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Energy and Process Assessment Protocol For Industrial Buildings

Alexander M. Zhivov, Dahtzen Chu, Mike C.J. Lin, Michael Chimack, Donald Kasten, Alfred Woody, Jorma Pietilainen, Timo Kaupinne, Timo Husu, Curt Bjork, Erja Reinikainen, Eugene Shilkrot, Fritz Schmidt, and Walt Smith

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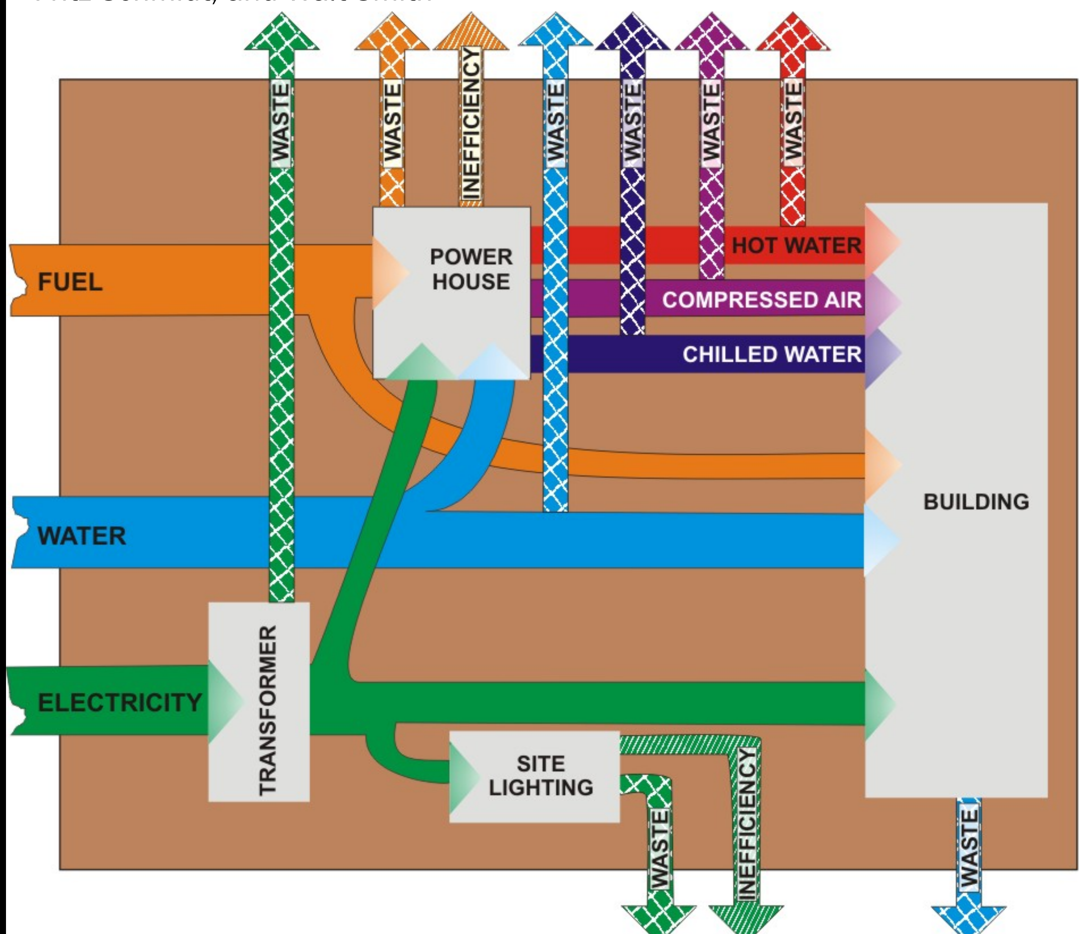

Energy and Process Assessment Protocol For Industrial Buildings

Alexander M. Zhivov, Dahtzen Chu, and Mike C.J. Lin
Construction Engineering Research Laboratory (CERL)
U.S. Army Engineer Research and Development Center
2902 Newmark Dr.
Champaign, IL 61824

Michael Chimack
University of Illinois at Chicago

Donald Kasten
Rutgers University

Jorma Pietilainen, Timo Kaupinnen
VTT

Timo Husu
Motiva

Alfred Woody
Ventilation/Energy Applications, PLLC

Curt Bjork
Curt Bjork Fastighet & Konsult AB

Erja Reinikainen
Olof Granlund Oy

Eugene Shilkrot
TsNIIPZ

Fritz Schmidt
ennovatis

Walt Smith
ETSI

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Abstract: As part of its research and reimbursable program, the Engineer Research and Development Center (ERDC) has developed the Energy and Process Assessment Protocol for Industrial Buildings and performed supporting showcase assessments at selected U.S. Army Installations. This effort was undertaken to help garrisons achieve energy reduction goals and meet EPAct 2005 mandates, and also to address production and maintenance needs at U.S. Army Arsenals and Depots. The Protocol is partly the result of an international collaboration under the International Energy Agency "Energy Conservation in Buildings and Community Systems" Annex 46, Subtask A.

A group of government, institutional, and private sector parties developed the Protocol to help users (facility energy managers, in-house energy assessment groups, companies providing energy assessments, universities conducting energy assessment, and Energy Service Performance Contractors) perform Industrial and Energy Optimization assessments. The Protocol is based on an analysis of information gathered from literature, training materials, documented and non-documented practical experiences of contributors, and successful showcase energy assessments at U.S. Army facilities. It addresses both technical and non-technical organizational capabilities required for successful assessment geared to identifying energy and other operating costs reduction measures without adversely impacting product quality, safety, morale, or environment.

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Preface

This study was conducted for the U.S. Army Corps of Engineers (HQUSACE) under project 0602784AT45, "Industrial Activities Readiness," Work Unit CFE-IAR, "Industrial Energy Optimization Technology." This is also a part of the IEA-ECBCS (International Energy Agency – Energy Conservation in Buildings and Community Systems) Annex 46 "Holistic Assessment Tool-kit on Energy Efficient Retrofit Measures for Government Buildings (EnERGo)." Technical monitors were Philip Columbus, Office of the Assistant Chief of Staff, Installation Management (OACSIM) and Paul Volkman, Installation Management Agency (HQIMA).

Parts of specific studies at different sites were conducted with contributions from participating installations: Rock Island Arsenal (RIA), under MIPR No. 4H13LRG040, for which the technical monitor was David Osborn, Energy Manager, RIA; Corpus Christie Army Depot (CCAD), under MIPR No. 5L32000010, for which the technical monitor was Shawn Smith, Energy Manager, CCAD; Sierra Army Depot (SIAD), under MIPR No. 4LFA04732B, for which the technical monitor was Robert Gee, Energy Manager, SIAD; Tobyhanna Army Depot (TYAD), under MIPR No. 4L3AB00192, for which the technical monitor was John Billack, Electrical Engineer, TYAD; Fort Stewart, under MIPR No. 5JCERB1040R, for which the technical monitor was Fred Louis, Energy Manager, Fort Stewart; Army Installations in Germany, for which the technical monitor was David Yacoub, Energy Manager, IMA/EURO.

The work was managed and executed by the Energy Branch (CF-E) of the Facilities Division (CF), Construction Engineering Research Laboratory (CERL). The CERL principle investigators were Dr. Alexander Zhivov and Dr. Mike Lin. Major contributors to the study were from the following organizations: University of Illinois at Chicago (Michael Chimack), Rutgers University (Donald Kasten), VTT (Jorma Pietilainen, Timo Kaupinnen), Motiva (Timo Husu), Ventilation/Energy Applications, PLLC (Alfred Woody), Curt Bjork Fastighet & Konsult AB (Curt Bjork), Olof Granlund Oy (Erja Reinikainen), TsNIIPZ (Eugene Shilkrot), ennovatis (Fritz Schmidt) and ETSI (Walt Smith). Special thanks are owed to the support of the Department of Energy Office of Industrial Technologies (DOEOIT), to the Federal Energy Management Program. UIC and Rutgers University were partially funded under subcontract with Oak Ridge National Labora-

tory by the Federal Energy Management Program (FEMP) Industrial Facilities Initiative. Additional information on FEMP's Industrial Facilities Initiative (and other FEMP Services) is available through Michaela Martin, Oak Ridge National Laboratory, tel. (865) 574-8688, or Alison Thomas, DOE Program Leader, tel. (202) 586-2099.

Dr. Thomas Hartranft is Chief, CEERD-CF-E, and Mr. L. Michael Golish is Chief, CEERD-CF. The associated Technical Director is Martin J. Savoie, CEERD-CV-T. The Director of CERL is Dr. Ilker R. Adiguzel.

CERL is an element of the U.S. Army Engineer Research and Development Center (ERDC), U.S. Army Corps of Engineers. The Commander and Executive Director of ERDC is COL Richard B. Jenkins, and the Director of ERDC is Dr. James R. Houston.

Unit Conversion Factors

Multiply	By	To Obtain
Acres	4,046.873	square meters
British thermal units (International Table)	1,055.056	joules
cubic feet	0.02831685	cubic meters
cubic inches	1.6387064 E-05	cubic meters
cubic yards	0.7645549	cubic meters
degrees (angle)	0.01745329	radians
degrees Fahrenheit	(F-32)/1.8	degrees Celsius
Fathoms	1.8288	meters
Feet	0.3048	meters
gallons (U.S. liquid)	3.785412 E-03	cubic meters
horsepower (550 foot-pounds force per second)	745.6999	watts
Inches	0.0254	meters
miles (U.S. statute)	1,609.347	meters
miles per hour	0.44704	meters per second
Mils	0.0254	millimeters
ounces (mass)	0.02834952	kilograms
ounces (U.S. fluid)	2.957353 E-05	cubic meters
pounds (mass)	0.45359237	kilograms
pounds (mass) per cubic foot	16.01846	kilograms per cubic meter
pounds (mass) per cubic inch	2.757990 E+04	kilograms per cubic meter
pounds (mass) per square foot	4.882428	kilograms per square meter
pounds (mass) per square yard	0.542492	kilograms per square meter
quarts (U.S. liquid)	9.463529 E-04	cubic meters
square feet	0.09290304	square meters
square inches	6.4516 E-04	square meters
square miles	2.589998 E+06	square meters
square yards	0.8361274	square meters
tons (force)	8,896.443	newtons
tons (2,000 pounds, mass)	907.1847	kilograms
Yards	0.9144	meters

1 Introduction

1.1 Background

A variety of industrial assessment methodologies, protocols and guides have been developed over the past years to improve energy efficiency of both private and government facilities. They have different emphases and thoroughness, which depend on the audit objectives and on the available human and financial resources. The current document is based on the analysis of the information available from the literature, training materials, documented and undocumented practical experiences of contributors, and successful showcase energy assessments conducted by a diverse team of experts at the U.S. Army facilities. The protocol addresses both technical and non-technical organizational capabilities required for successful assessment geared toward identification of energy and other operating costs reduction measures without adversely impacting product quality, safety, morale, or environment.

1.2 Objectives

The objectives of this work were to:

1. Develop energy and process assessment protocols for industrial facilities.
2. Demonstrate the developed protocols through showcase studies at selected Army Depots and Arsenals to improve Army installation mission readiness and competitive position.
3. Provide checklists as well as recommendations of relevant useful DOE or IEA sponsored energy analysis software tools.

1.3 Scope

This document describes a (working) version 1.0 of an energy and process assessment protocol for industrial facilities, and provides checklists for energy inefficiencies and wastes, and a consolidated list of typical energy conservation measures (ECMs). The results of showcase studies at selected Army Depots and Arsenals associated with this project are documented in a separate report (Zhivov, et al. 2006).

Industrial energy assessment includes: analysis of energy streams in the target (e.g., building stock, building, system, etc.), existing saving poten-

tials and development of recommendations on an effective utilization of energy. The scope and depth of the assessment may vary. The depth of energy audits can be classified into three levels. These levels differ in their objectives, scope, methodology, procedures, required instrumentation, and approximate duration. A *Level I* audit is a preliminary energy and process optimization opportunity analysis consisting primarily of a walk-through review and analysis existing documents and consumption figures. A Level I audit would normally be followed by a Level II audit to verify the Level I assumptions, and to more fully develop the ideas from the Level I screening analysis. The Level II effort includes an in-depth analysis in which all assumptions are verified. The end product will be a group of "appropriation grade" process improvement projects for funding and implementation. Lastly, the *Level III* audit is a detailed engineering analysis with implementation, performance measurement and verification (M&V) assessment, and fully instrumented diagnostic measurements.

1.4 Mode of Technology Transfer

The protocols developed during this work and the associated energy optimization assessment tools will be used in future showcase studies. The information will be disseminated through workshops, presentations, and professional industrial energy technology conferences to:

- DoD Facility Energy Managers and in-house energy assessment groups,
- Companies providing energy assessment,
- Universities conducting energy assessment, and
- Energy Service Performance Contractors.

This report will also be made accessible through the World Wide Web (WWW) through URL:

http://www.cecer.army.mil

2 Energy Audits Scope and Depth

An industrial energy assessment includes an analysis of energy streams in the target (e.g., building stock, building, system, component), an analysis of existing saving potentials, and development of recommendations for more effective energy use. The scope and depth of the assessment differ in their objectives, methodology, procedures, required instrumentation, and approximate duration (Figure 1).

The Protocol distinguishes between the pre-assessment phase (Level 0: selection of objects for Energy Assessments and required composition of the team) and three levels of energy audits with different depths. Each of these three levels may be implemented in different ways: a simplified or a more detailed assessments, depending on the energy usage and other data availability.

During the selection phase, one can choose from a building stock those buildings that have the most promising energy saving potential. Similarly, one can select from a specific building the systems to be audited or, from a system, the components to be considered for more detailed analysis.

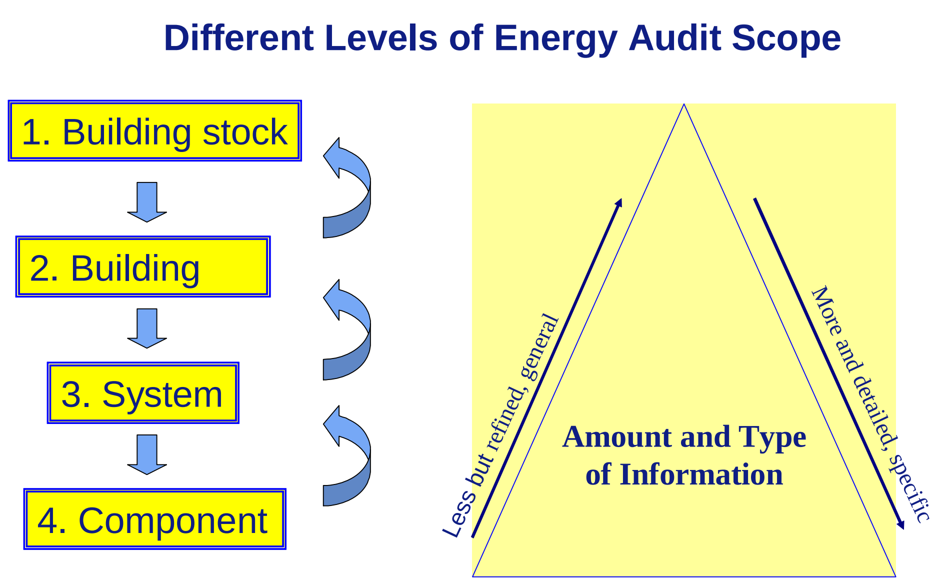

Figure 1. Different levels of the energy audit scope.

These decisions might be affected by various influences such as political, social, and energy consumption aspects, as well as financial considerations. During this phase, it is also reasonable to consider a spectrum of possible ways to implement and finance the implementation of the ECMs identified during the audit. A broad spectrum of strategies is available, ranging from funding and implementing by the owner/end-user, constructing using energy conservation implementation program funding or similarly centrally funded programs, using energy saving performance contracts (ESPC), or a combination of these options.

A *Level I* audit (qualitative analysis) is a preliminary energy and process optimization opportunity analysis consisting primarily of a walk-through review to analyze and benchmark existing documents and consumption figures. It takes from 2 to 5 days, and identifies the dollar potential for process improvements and energy conservation to the bottom-line. No engineering measurements using test instrumentation are made.

The existing processes are challenged, and new practices and technologies are considered. If the consumption figures are not available (e.g., due to the absence of metering), which is typical for many industrial facilities and manufacturing processes, the Level I audit can be based on analysis and estimates by experienced auditors.

A Level I audit would normally recommend that the installation perform some metering, which could be followed by a Level II audit to verify the Level I assumptions, and to more fully develop the ideas from the Level I screening analysis.

A *Level II* audit (quantitative analysis) includes an industrial process optimization analysis geared towards funds appropriation; this analysis uses calculated savings and partial instrumentation measurements with a cursory level of analysis. The Level II study typically takes 5 to 10 times the effort of a Level I, and could be accomplished over a 2- to 6-month period, depending on the scope of the effort. The Level II effort includes an in-depth analysis in which the most crucial assumptions are verified. The end product will be a group of “appropriation grade” energy and process improvement projects for funding and implementation.

Finally, the *Level III* audit (continuous commissioning) is a detailed engineering analysis with implementation, performance measurement and verification (M&V) assessment, and fully instrumented diagnostic meas-

urements (long term measurements). This level takes 3 to 18 months to accomplish. For ESPC projects, the *Level III* audit is prolonged until the end of the contract to guarantee that all systems and their components operate correctly. Table 1 shows composition and thoroughness of auditing activities for the different auditing levels.

Figure 2 shows the main methods (monitoring, calculation and others) to perform the audits, some of which are described in more detail later in this report. The Protocol distinguishes energy assessment levels primarily through the amount of information necessary and available and a level of effort. Thus, a simple Level I analysis in some cases might correspond to a more in-depth Level 0 assessment.

Table 1. Energy auditing activities for different levels.

Auditing Activities	Levels of Energy Audits		
	Level 1	Level 2	Level 3
Energy consumption and specific characteristics	X	X	X
Rough evaluation of mechanical systems, the building envelope,[1] industrial processes, interviewing of technical staff	X	X	X
Analysis of technical documents		X	X
Interviewing of the facility, employees, workers		X	X
Measurements, at minimum level		X	
The measurements, at thorough level			X
Heat balances		X	X
Estimation of saving potential	X	X	X
Development of ECM list with approximate cost analysis		X	
Investment proposals with a life-cycle cost analysis (LCCA)			X

[1]To estimate condition of the building envelope

2.1 Target Audience

This Energy Assessment Protocol is developed to assist the following target groups of users and representatives of building owners:

- Facility Energy Managers and in-house energy assessment groups,
- Companies providing energy assessment,
- Universities conducting energy assessment, and
- Energy Service Performance Contractors.

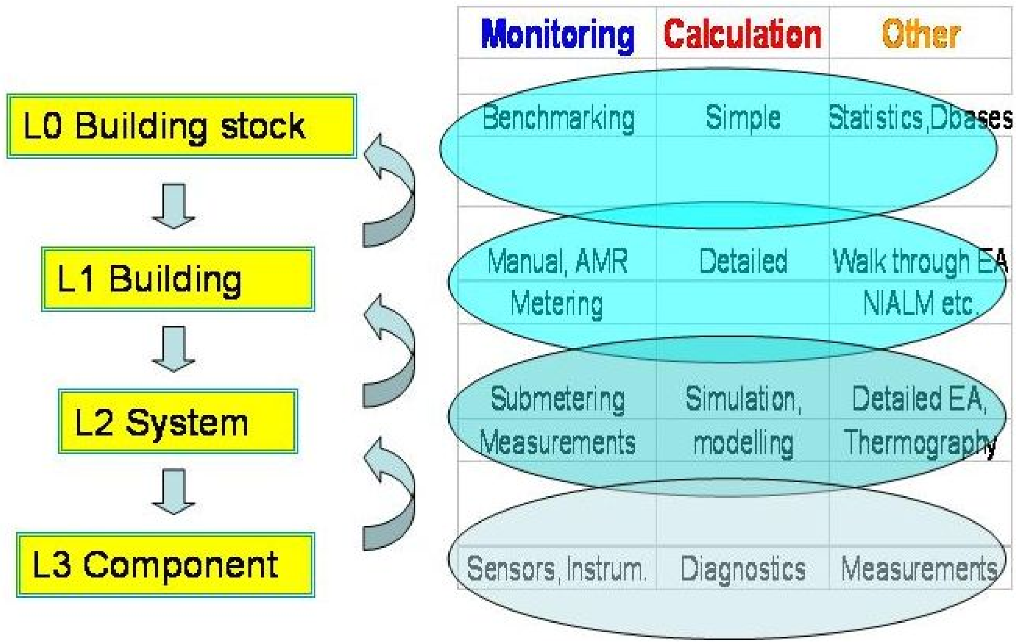

Figure 2. Main methods used to perform the audits.

The key elements that guarantee success of the Energy Audit are:

- Involvement of **key facility personnel** who know what the problems are, where they are, and have thought of many potential solutions;
- The facility personnel sense of "ownership" of the ideas, that in turn develops a commitment of implementation; and
- A focus on site-specific, critical cost issues, which if solved, will make the greatest possible economic contribution to a facility's bottom line. Major potential costs issues include: capacity utilization (bottlenecks), material utilization (off spec, scrap, rework), labor (productivity, planning and scheduling), energy (steam, electricity, compressed air), waste (air, water, solid, hazardous), equipment (outdated or state-of-the-art), etc.

From a strictly cost perspective, process capacity, materials, and labor utilization can be far more significant than energy and environmental concerns. All of these issues, however, must be considered together to achieve the facility mission in the most efficient and cost-effective way.

2.2 Target Facilities

The principles described in this protocol can be used to assess industrial buildings with the following manufacturing or maintenance processes:

- Foundries
- Welding Shops

- Vehicle Maintenance, including Dynamometer Testing Cells
- Painting, paint stripping
- Plating
- Parts Cleaning
- Metal Working
- Heat Treatment
- Loading, Assembly and Packing of munitions
- Explosive/Propellant Production
- Wood Working
- Controls/Electronics Testing and Repair.

It can be also used as guidance for assessment of buildings with similar processes or to perform partial energy assessment of other industrial buildings addressing the building envelope, HVAC systems, compressed air, heat supply systems, etc.

2.3 Protocol Scope

1. This protocol applies to government-owned and/or operated industrial facilities.
2. It pertains to all functions necessary to the fulfillment of the manufacturing, service, or supply activities conducted at the above-mentioned facilities.
3. The protocol addresses major energy sources and areas of end use, including:
   a. HVAC and automation systems and their operation.
   b. Heat and chilled water distribution systems and central energy plants
      (1) Building envelope.
      (2) Electrical systems
      (3) Internal loads, such as lighting, compressed air, motors, drives, etc.
      (4) Production processes.
4. Enables the performing entity to compile a report documenting the resource consuming activities toward:
   a. Identifying wasteful practices.
   b. Prioritizing among conservation opportunities.
   c. Implementing best practices.
   d. Investing in resource-conserving technology upgrades.
5. The scope of this protocol is limited to Levels I and II audits. For industrial buildings, the simple versions of the implementation are preferred or even the only possible option.

2.4 Energy and Process Auditing Team Requirements

Designers, consultants, contractors, material and equipment suppliers should be familiar with the energy performance of the ***specific*** field they are experts in. Structural designers and consultants should be familiar with heat losses through the building shell and what insulation should be added. Heating and ventilation engineers should be familiar with the energy performance of heating, ventilation, compressed air, and heat recovery systems. Designers of electrical systems should know energy performance of different motors, VFD drives and lighting systems. Industrial process and energy audit requires knowledge of process engineers specialized in certain processes. Most of the knowledge necessary for energy audit is a part of already existing expertise.

The expertise of energy auditing is not very strict and separate field of skills, methods and procedures, but a combination of skills and procedures from different fields. However, energy and process audit requires a **specific talent of putting together existing ways and procedures to show the overall energy performance of building and processes it houses, and how the performance can be improved.**

A well-grounded energy and process audit team should have expertise in the fields of HVAC, structural engineering, electrical and automation engineering and, of course, a good understanding of production processes.

A critical for any energy and process audit team members is a capability of applying **"holistic" approach** to the energy sources and sinks in the audited target (installation, building, system, or their elements) and **"stepping outside the box."**

Better **understanding of needs of process and building end users** results in a better value provided to them. Important members of the team are end users themselves. **Participation** of management, production, O&M staff, energy managers and on-site contractors is critical for collecting information, ideas development, and getting a sense of "ownership" of the ideas, that in turn develops a commitment of implementation. Involvement of **key facility personnel,** who know what the problems are, where they are, and have thought of many potential solutions is the key to success of the energy audit.

The crucial point is that the existing use and distribution of energy and utilities (heating energy, electricity, water) has been evaluated for the level

accurate enough and the saving potential, measures needed, priorities (if there are any) and payback time of each single measure is presented. The building owner/user can make decisions based on this data.

3 Protocol

3.1 What the Protocol Includes

The protocol establishes the objectives, scope, methodology, procedures, required instrumentation and approximate duration for three levels of industrial analysis. Checklists and recommendations of relevant useful DOE or IEA sponsored energy analysis software tools will also be provided.

3.2 Scope of an Industrial Energy Assessment Audit

An audit may include different components and activities depending on the audited target. In small production buildings or a maintenance shop, the activities and the objectives may be different that those in complex industrial buildings. Audit objectives and available financial and human resources for the audit as well as available documents and statistical information of the audited target (building, complex of buildings, etc.) provide a framework for the auditing activities.

Industrial energy audit shall focus on site-specific, critical cost issues, which if solved, will make the greatest possible economic contribution to a facility's bottom line. Major potential costs issues include: capacity utilization (bottlenecks), material utilization (off spec, scrap, rework), labor (productivity, planning and scheduling), energy (steam, electricity, compressed air), waste (air, water, solid, hazardous), equipment (outdated or state-of-the-art), etc.

From a strictly cost perspective, process capacity, materials, and labor utilization can be far more significant than energy and environmental concerns. All of these issues, however, must be considered together facility mission in the most efficient and cost-effective way.

Therefore, there may be two ways to approach the problem:

1. If the general costs are too high (or if the building needs renovation anyway) one should start a cost assessment and an energy assessment audit (as part of the cost assessment). This renews the processes, and also (with little extra money) can achieve an energy optimization.
2. If the energy costs are too high, there may be two alternatives:
    a. One may reduce energy costs without changing the processes, the building, or the equipment. This corresponds to adapting the con-

sumption to the energy demand and requires long term measurements and analyses (Level 2 audit) to become sustainable.

b. Alternatively one may identify possibilities to reduce demand. These include redesign of processes, retrofitting of the building envelope or replacing HVAC components by more energy efficient ones.

4 Level I Audit

4.1 General Information

Level I of Industrial Energy Audit includes:

- **Step 1. Preparation Activities** An important part of the preparation activities is building relations by the team leader with the customer, development of professional trust and a buy-in starting with the top management and potential financiers, and all the way to the building occupants. During this step a small part of the team shall collect the preliminary information and calculate specific energy and water consumptions, review design and other technical documentations of the audited target, review manufacturing processes and uses of energy, materials, production costs and bottle-necks. Thorough preparation toward understanding the basic aspects of the facility, its processes, and procedures is expected to ensure effective use of time during the on-site assessment as well as provide useful data for analyzing opportunities and documenting results.
- **Step 2: On-site Analysis**. The make-up of the assessment team and their familiarity with the facility(s) being served will largely determine the procedure for conducting and the expected duration of the on-site assessment. The size and complexity of the target and its systems will also determine the time required to perform the on-site assessment.

This step includes tour of the target, interviewing of production and O&M personal and building occupants concerning productivity, thermal comfort, lighting level, and IAQ. An important part of this step is development of process and energy flow diagrams into and out of the building/ building complex, e.g., power and fuel, supplied to the building/ installation (input), building heating and cooling (outputs), fuel loss through handling, heat loss in distribution pipelines, heat loss in air compressor (energy waste).

Analysis of energy flows and balances is a useful tool to identify energy waste and inefficiencies that are potential areas of energy conservation. A convenient way to present energy flows is a Sankey diagram. Figures 3 and 4 show examples of the energy flow into a site and building electrical energy and heat flowcharts.

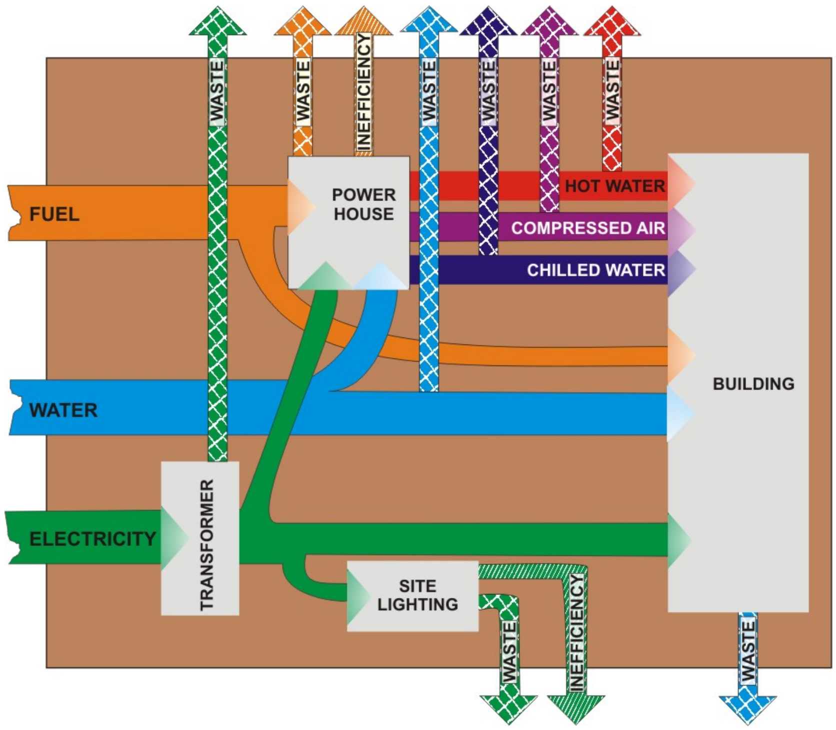

Figure 3. Site energy flows.

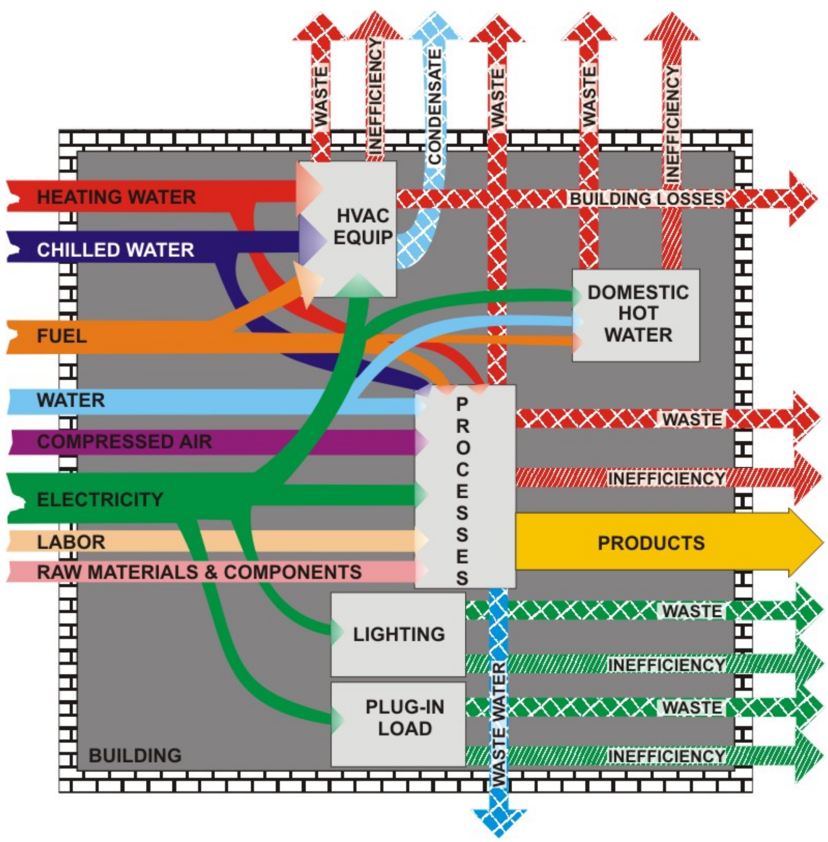

Figure 4. Building energy flows.

Figures 3 and 4 clearly show that the analysis of energy flows and balances is quite complex. The analysis requires tools and models consistent with the selected tool, then these models must be adjusted to the actual case.

If detailed energy consumption data is unavailable, it is possible to identify and analyze potential wastes and inefficiencies (shown by arrows in Figures 3 and 4) and select corresponding sets of ECMs. Experienced auditors might recommend how to rank and quantify application of these ECMs.

If the selected tool and model used allows for a quantitative analysis, the total building or site energy usage becomes more transparent, allows for an evaluation of the synergy of the proposed ECMs, and for ranking them based on the life-cycle cost analysis.

These diagrams provide an overall view of sources of waste and inefficiency. Heat is given off by equipment in the power house, or is lost in the distribution systems that deliver tempered fluids to systems that require them. Waste is defined as use of excess energy due to a system or piece of equipment not performing up to its capabilities. This can be caused by poor maintenance, improper operation and/or a need to replace worn out elements. Inefficient equipment can also lead to excessive energy use.

The efficiency of the boilers results in excess energy in the flue gases and blowdown water. Efficiency improvements can be accomplished by investments that add additional or new components to a system. These investments must be cost effective thus it may not be wise to pay more for highly efficient equipment that is seldom used.

The energy flow into individual systems can also be illustrated by a Sankey diagram. A number of these diagrams can be found in "Typical areas to look for improvement" (p 25). Systems presented in this manner are building envelope, HVAC, lighting, painting processes and other processes.

Step 3: Reporting Activities. A report should be prepared documenting the results of the assessment team's findings. The level of detail provided in the report will be a function of the context for any subsequent follow-up work and the motivation that inspired the report's commissioning.

During the previous steps a lot of technical documents and other information have been reviewed, measurements have been made, people have been interviewed. The report shall contain the list of proposed ECMs and, depending on the Level of the energy audit, different level of details and

analysis of the grounds, facts and economics on which this proposal is based. For example, a report on the Level 1 assessment may include educated estimates, provide cursory economic analysis, and produce a list of no-cost, fast payback ideas. The higher levels of assessment shall include a detailed LCC analysis.

4.1.1 Preparation Step

4.1.1.1 Preliminary Data Required

Data collection prior to going to site will save time, money and will foster partnership between the energy assessment team and end-users. The following data is desirable:

- Site master plan and building design drawings that provides architectural details (window and floor area, roof area, building volume etc.) mechanical and electrical information (HVAC, plumbing, lighting and electrical distribution system types, sizes, and control). Note these design drawings may lack information regarding the current building situation and a field check of the drawings is always recommended.
- Information on different shops area, volume, occupancy patterns, typical building/shop usage, process layouts and other relevant information
- Production hours for different areas/shops, No. of workers in each shift
- Operation time for different processes
- Any information on existing ventilation systems (layouts, airflows, controls, operation instructions)
- Information on compressed air systems, boiler and chilled water plants, central child water and hot water/steam distribution systems
- Heat and power prices (per unit)
- Available information on energy use in recent years (electricity, oil, gas, etc.), site energy records of metered/sub-metered energy consumption, statistical data from the utility or/and bills, regarding electricity, oil, gas etc. (for details see CIBSE 18.6.1.1)
- Projected energy price increase (to be used in this project)
- Key information related to production (number of units produced, use of raw materials, etc.) in different areas (past and the best estimates for the near and long-term future)
- Recently completed energy improvement measures and results
- Requirement to indoor air quality and thermal conditions in shops
- Permits for exhaust air systems
- Reports on recent studies (including ESCO proposals).

4.1.2 On-site Analysis

Pre-assessment visit. Following response to a data collection request, a team leader needs to make a pre-assessment visit to the site to:

- Discuss the forthcoming assessment with end-users
- Conduct a "Level 0" analysis to familiarize himself with the site
- Select from the building stock those buildings that are most promising for an energy audit, to select the systems in those buildings to be audited, or from a given system, the components to be considered for more detailed study
- Collect any further information available (which saves time when the team arrives on site)
- Based on the pre-site visit, determine necessary technical skills required to conduct the surveys, optimal size of the team, a number of sub-teams, and duration of the assessment based on the scope of the study. Figure 5 shows an example of the team composition and assignments. Figure 6 shows a detailed daily schedule.

4.1.3 Preliminary Energy and Process Optimization Opportunity Analysis

Process. Team members have to **arrive on site prepared** and armed with the knowledge of information obtained prior to the site visit. Upon arrival at site on the scheduled assessment date team conducts a **kick-off meeting** and **a team-building** session between the plant's management (preferably top level), staff responsible for planning, manufacturing, engineering, energy management, mechanical systems, S&H and other major stake-holders, and the members of the assessment team. The assessment team briefs the customer's side of the team on the goal, objectives and the time schedule of the on-site assessment and requests time slots to interview major players from the customer's side. Members from the customer's side brief the assessment team members.

Assessment team members from the plant site provide an overview of the plant operations with details of equipments and systems involved. This will give the audit team a good idea of current operations and upgrade that might be appropriate. They also learn about completed and ongoing energy and other retrofitting projects, production processes bottlenecks, needs, and perceived problems and ideas to overcome them. Ongoing or planned construction or production LEAN Program projects may be a great time for the complementing energy projects, since energy related projects can have a low marginal cost when incorporated into major refurbishment work, e.g., roof repair or renovation of production process.

Team Assignments					
U.S. Army Installation Energy Assessment					
17–28 July 2005					
Team Black		Team Grey		Team Gold	
Central Energy Plants[1]		DOL Maint. Facilities, Unit Motor Pools[2,3]		Barracks/Admin Facilities, Dining & Training Facilities[3]	
Co-Lead		**Lead**		**Lead**	
Mechanical Engineer ↔		Mechanical Engineer ↔		Mechanical Engineer	
Mechanical Engineer ↔		Mechanical Engineer ↔		Mechanical Engineer	
Energy Engineer		Mechanical Engineer		Electrical Engineer	
Energy Engineer (Boilers)		Electrical Engineer		Building Research Scientist	
Energy Engineer (District Heating)		Process Engineer			
Facilities (Building No.)		Facilities (Building No.)		Facilities (Building No.)	
350		***230***		100	
1196/1197		***241***		212	
1412	CEP	270/271		256	
3001		***1160/1170***		405	
HAAF:		1245		***608***	
110	3.5 MMBtu, Dual	1265		620 – 623	
1323	18 MMBtu, Dual	1320		632 – 639	
1451	5 MMBtu, Gas	1340		***642 – 649***	
1032	2.1 MMBtu, Gas	1620		712 – 715	
8585	218 MMBtu, Oil	1630		720	
1032	Size Unkn.	1720		810	
1323	Size Unkn.	4502		5050	
1451	Size Unkn.	4577/4578		5051	
		DOL Modulars – various			
Those facilities highlighted in red and bold were reviewed by the ESCO for lighting and water, and HVAC controls. (See separate file of results.)					
Notes: [1]Includes: Army Airfield and Main Site. [2]Includes: Painting, Welding, HVAC, Lighting, Compressed Air, General Maintenance [3]Includes: The Building Envelope.					

Figure 5. Example team composition and assignments.

Saturday	23-Jul				
		0800 - 1200	AAR of weeks activities and Begin Phase II		
		1200 - 1300	Lunch		
		1300 -	Personal Time		
Sunday	24-Jul				
			Personal Time		
Monday	25-Jul				
		0900 - 1700	**Team Black**	**Team Grey**	**Team Gold**
		~1800	Dinner		
		1900 - 2000	AAR of days activities		
Tuesday	26-Jul				
		0900 - 1700	**Team Black**	**Team Grey**	**Team Gold**
		~1800	Dinner		
		1900 - 2000	AAR of days activities		
Wednesday	27-Jul				
		0900 - 1700	**Team Black**	**Team Grey**	**Team Gold**
		~1800	Dinner		
		1900 - 2000	AAR of days activities		
Thursday	28-Jul				
		0900 - 1100	Develop Results and Prep for Out-Brief		
		1000 - 1200	Out Brief to DPW Staff on Findings of Best Candidate		

Saturday	23-Jul				
		0800 - 1200	AAR of weeks activities and Begin Phase II		
		1200 - 1300	Lunch		
		1300 -	Personal Time		
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			Personal Time		
Monday	25-Jul				
		0900 - 1700	**Team Black**	**Team Grey**	**Team Gold**
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Wednesday	27-Jul				
		0900 - 1700	**Team Black**	**Team Grey**	**Team Gold**
		~1800	Dinner		
		1900 - 2000	AAR of days activities		
Thursday	28-Jul				
		0900 - 1100	Develop Results and Prep for Out-Brief		
		1000 - 1200	Out Brief to DPW Staff on Findings of Best Candidate		

Figure 6. Example detailed daily schedule.

After the kick-off meeting the assessment team conducts the **guided plant tour** starting from the point of entry of raw materials to the shipment area, and includes the point of energy/fuel supply lines and different mechanical and energy systems. The scope of the tour shall be broader than the scope of the assessment to understand the "big picture." It is important to have a competent guide(s) for each area to provide in-depth information and answer questions.

Upon completion of the tour, the team **discusses the potential energy-saving opportunities**, compiles a list, and makes assignments to team members for subsequent data collection.

Upon completion of data collection, potential energy conservation opportunities/measures **(ECM) are brainstormed by the team** with a participation of the **responsible personal** to reach a **consensus** and their **buy-in**. Be sure to listen to and follow up on the personal's questions or ideas.

The preliminary results of the assessment are then outlined and **reported to the management for their approval** and further development of recommendations.

Request that plant personal supply follow-up data. Discuss reporting requirements.

Sort out plans and ideas before leaving site.

Site plan and building drawings information analysis

The review of the collected site plan and building drawings will provide a basic understanding of the areas to be evaluated for efficient use of energy. The site plan will identify all the buildings located on the installation as well as the energy distribution systems that supply those buildings. The central heating/cooling plants with the piping that feeds the buildings should be presented. Also those building scheduled for demolition as well as those new buildings planned should be exhibited. A list of existing buildings with their area identified should be part of the master plan documents.

The building drawings will characterize the buildings being evaluated as to sources of energy waste and where improvements can be made that would

be cost effective. Building design drawings are divided by design discipline: Architectural, Structural, Civil, Electrical and Mechanical. The architectural drawings show the size and shape of the building The building's features such as windows, doors, wall and roof construction, etc. are found on these drawings.

The structural drawing indicate the supporting members in the building structure and their assembly to provide a building that is stable and able to withstand the forces that will be imposed on it. Often the structural information is combined with the architectural and presented on the architectural drawings.

The civil drawings show site features such as areas for vehicle movement and parking, utility distribution (water, natural gas, electricity, sewer, etc.), rain water drainage, and locations of plants that form the landscape.

The electrical drawings show how the incoming electricity is reduced in voltage and distributed to substations and electrical panels. Also shown is the lighting design in terms of lighting fixtures and their location.

The mechanical drawing provide information regarding the heating, cooling and ventilation systems as well as the plumbing, water treatment, compressed air, and process cooling water. Sizes and capability of required equipment are specified, location and size of distribution systems are shown, and details for installation of the components of the system are provided. Drawings that show the control system for the various systems can be found with the mechanical, electrical, or a standalone control drawing set.

The information contained in the drawings is important to understanding the building's operation and needs. The following items can be determined from a good set of building drawings:

- window area and U-values, orientation to the path of the sun
- wall areas and U-values, orientation to the path of the sun
- roof area and U-values
- service areas of ventilation units
- designed rates of ventilation
- Location, size, and efficiency of electrical and mechanical equipment
- Original method for system control and operation
- Buildings served by central systems and the operating temperatures and pressures of those systems.

4.1.4 Invoice Data Analysis

The energy bills yield information that when analyzed may provide recommendations before the visit such as energy demand rescheduling, avoidance of late payment penalties, and energy ratcheting errors. Information obtained from utility billing includes (with examples):

- Electrical Rate Data:
  - Total Energy Usage (kWh)
  - Total Energy Usage (MMBtu)
  - Total Reactive Charge $
  - Total Electricity Cost $
  - Total Other Cost $
- Natural Gas Rate Data:
  - Total Energy Usage (CCF)
  - Total Energy Usage (MMBtu)
  - Usage Cost $
- Fuel Oil:
  - Total Energy Usage (gal)
  - Total Energy Usage (MMBtu)
  - Usage Cost - $
- Average Costs:
  - Electricity - ($/kWh)
  - Electricity - ($/MMBtu
  - Electricity - ($/kW)
  - Natural Gas - ($/MMBtu)
  - Fuel Oil - ($/MMBtu).

4.1.5 Energy Cost, Tariff, and Consumption Analysis

The Level I audit should include an analysis of energy consumption, energy costs, energy tariffs and peak demand. This information is usually available from the energy supplier. The facility management's energy monitoring may include consumption data, but tariff and peak demand data is not usually included in the monitoring.

Specific consumption figures are one thing to consider, but there is much more valuable data in the energy bills.

4.1.6 Electricity

If hourly power demand data is available from the utility, a quick look on the power demand variations during a typical summer and winter week will give an idea of the day-time and night-time energy profiles.

Some typical questions for the analysis:

- What is the difference in day-time power demand in summer and in winter? Is this due to electrical heating or additional lighting?
- Does the peak demand occur in summer or in winter? Is it caused by heating or cooling demand?
- Is there electric heating or frost protection heating? What is the estimated cooling capacity? Do these explain the differences in power demand?
- What is the difference between day and night time power demand? Or between the operation or production time / off-time demand? What causes the off-time consumption? Is there some unnecessary energy use during the night?
- How does the power demand vary during the week? What causes the weekend consumption?
- How does the power demand vary in peak production time and a more quiet time?
- What is the peak demand time (yearly energy consumption kWh divided by peak demand kW)? How does this relate to the working hours in the facility? If the peak demand time is long and about the same as the hours of operation, the consumption does not vary very much and is caused by a very constant load. A short peak demand time indicates a high energy demand occurring at extreme conditions.

The energy tariff analysis is necessary for finding the correct energy price for the saving measures occurring at different times of the day / week / year. Typical questions for the analysis:

- What are the elements in the tariff? Is there a difference in energy price for the day and night? For summer and winter? What are the fixed costs?
- How does the peak demand connect to the energy tariff? If there is a peak demand cost, could this be reduced by peak shaving?
- Is there a reactive power charge?
- What are the main cost elements in the energy bill? Can peak shaving or power factor correction (improving reactive power compensation) reduce costs?

- Are there alternative utility tariffs available?
- If energy saving measures are implemented how will the consumption and peak demand change? What is the optimal tariff in the new situation?

4.1.7 District Heating, Gas

Similar questions are valid for district heating and gas supply. There supplied capacity data is not available, the analysis must be based on cost and energy data.

Typical questions for the analysis:

- What are the elements in the tariff? Is there a difference in energy price for summer and winter or other seasonal variation?
- What are the fixed costs? Do the fixed costs depend on the peak heating demand or something else?
- What is the monthly cost and consumption profile like? What is the difference in the consumption between summer and winter months? If the variation is not remarkable, the main consumption may be caused by domestic hot water or system/network losses.
- Peaks in heating demand occur between November and March. Other peaks are caused by production processes or domestic / process hot water use.

If there is a gas boiler, the boiler losses and other system losses should be analyzed. There may be saving possibilities in eliminating unnecessary heating or unnecessary losses. For heating the losses of the heat distribution may be a critical issue.

Typical questions for the analysis:

- What are the flue gas losses? How are stack losses / uncontrolled ventilation losses prevented?
- Is there a remarkable heat loss from the boilers?
- Are all boilers connected to the heating network all the time?
- What causes heat demand in the summer time? Domestic hot water use or processes?
- What is the heating network temperature in winter and in summer? Is there a constant water flow in the network all the time?
- What are the network losses without any actual consumption in the facility? This can be analyzed during the summer time when there is no demand for heating.

- Is there a record on the burner running hours? Analyzing the monthly or yearly running hours will give an idea of the heat demand - does the burner stay on for long periods of time or fire occasionally?

4.1.8 Water

Water may be a significant cost issue in some facilities where the process requires large quantities of water. Water may be heated for processes or for domestic use, leading to a high heating energy demand.

Water suppliers may have different tariffs. The costs and consumption should be analyzed. Typical questions for the cost analysis:

- What are the elements in the tariff? Is there a cost for water supply and sewage water? What are the fixed costs?
- How does the consumption vary in the winter and summer months?
- How much water is used in production processes? Does the water consumption reflect the changes in the production?
- Is water used for cooling purposes or to supply water to cooling towers? Is the cooling demand constant?
- Could cooling water be recycled or is closed circuit cooling possible?
- Is there waste heat from processes available for pre-heating domestic or process hot water?

4.1.9 Energy Consumption Breakdown Analysis

Based on the consumption data, some selective measurements and observations on site a rough breakdown of the electricity and heat consumption should be calculated. Simple power demand or temperature measurements, air flow and water flow assumptions based on fan or pump capacity may give a rough idea of the main consumers. The saving possibilities in the main areas of consumption are the most important ones. In Level I audits the auditor should concentrate on these.

Typical questions are:

- What are the main areas of consumption in heating, electricity and water?
- If the site consists of several buildings and there is only one energy meter, which are the most important buildings?
- If there are energy consuming processes, which are the most important ones?
- Which parts of the facility are in operation 24 hours a day?

- Which processes and equipment have the highest power demand? Is the demand just a peak on going on for a longer time?
- How does the heating energy demand divide into heating, ventilation and domestic hot water / process hot water?
- How does the electricity demand divide into lighting, HVAC equipment and process equipment?

4.1.10 Plant Tour

During the guided plant tour:

- Make sure the team understands energy usage in the plant and billing schedules involved.
- Ask questions to gain a basic understanding of plant processes yielding waste and to identify point sources of waste generated in plant and solicit energy end users for their input in solutions for energy and waste reduction.
- Ask for approximate quantitative data for major waste streams (amounts and associated costs).
- Request and review available waste data records (and energy bills if necessary).
- Clarify process details.
- Confirm point sources of waste.
- Clarify causes of waste production and energy consumption.
- Characterize waste handling/processing procedures.
- Generate preliminary ECM ideas.
- List areas/processes for which additional quantitative data is needed for later analysis.

4.1.11 Typical Areas To Look for Improvement (Site Considerations)

Each component of the site energy systems needs to be evaluated for energy waste and efficiency. Figure 2 (p 6) shows the energy flow for the site systems. It is likely that a manufacturing complex will have a power house where equipment that provides utility type services to the buildings and processes is located on the site. In the power house, there could be boilers to generate steam or hot water for the heating needs of the site's buildings and processes. Fuel is consumed in the boilers and a percentage of the heating energy found in the fuel is transferred to the steam or hot water. Pumps are required to move water through the equipment and fans are needed to supply air for combustion of the fuel. There could also be chillers in the powerhouse to cool the chilled water needed by the buildings and processes. Pumps are required in this system to circulate water to the

buildings and to the cooling towers. Cooling towers are needed to release the heat removed by the chillers from the chilled water to the atmosphere. The powerhouse may also have air compressors that generate compressed air for process needs. Heat created by compressing the air is removed by cooling towers using water circulated through coolers on the compressor. Table 2 lists energy waste and inefficiency for these systems.

Table 2. Central power plant waste and inefficiency.

System	Waste	Inefficiency
Boilers	More than 5% ? boiler blow down	More than 20% excess oxygen in flue gases
	Failure to return condensate	Flue gases more than 150 °F warmer than leaving hot water or steam temperature
	Leaks at gaskets, fittings and valves	Blowdown water warmer than 140 °F
	Leaking steam traps	Use of dampers to control of air flows
	Over venting the deaerator	Surface temperature of boiler, pipes or other hot surfaces greater than 125 °F
	Poor water treatment	Use of continuous lit pilots
	Dirty burners	Boiler cycling on and off at low loads
	Improper operating dampers	Vent gases released outdoors warmer than 200 °F
	Inoperable, uncalibrated or poorly adjusted controls	Use of small inefficient steam turbines (less than 65%)
	Boiler tubes not cleaned in two years	Use of cooling tower or river water to condense steam turbine exhaust steam
	Damaged or missing refractory	Use of PRV to provide pressure reductions
	Combustible gases in the flue exhaust	Use of a boiler having an efficiency less than 70%
	Excessive venting of steam	Use of steam to atomize oil
	Steam pressure greater than required by processes	Use of inefficient burners
	Steam line serving unused areas	Flue oil too cold for good atomization
		No automatic stack damper
		Boiler in remote location to area served
Chillers	Water flow through shut down equipment	Use of constant chilled water temperature
	Dirty heat exchangers	Use of constant cooling tower water temperature
	Inoperable, uncalibrated or poorly adjusted controls	Use of air cooled chiller equipment
	Imbalanced water flow in system	Use of oversized equipment
		Excessive energy use at part load conditions

System	Waste	Inefficiency
Air Compressors	Running standby dryer	Use of oversized equipment
	Leaks at gaskets, fittings and valves	Use of warm building air for compressors air intake
	Dirty heat exchangers	Use of refrigerated air dryers
	Fouled air/oil separators	Use of modulation-controlled air compressors at part load.
	Lack of control of lubricating oil temperature	Lack of compressor system control system
	Failure to utilize heat from compressor	Heated air greater than 150 °F exhausted outdoors
	Inoperable, uncalibrated or poorly adjusted controls	
	System pressure greater than required by users	
	Dirty air filters	
	Continuous air bleeds	
	Compressed air used for cooling, agitating liquids, moving product or drying	
	Providing compressed air to unused areas	
	Leaks greater than 5% of system flow	
Cooling Towers	Dirty distribution nozzles	Blowdown from supply header or tower basin
	Leaks and excessive blowdown	Control of fans and pumps not based on water temperature
	Imbalance of flow over towers	Fan blades not adjusted for load or season
	Splash bars and drift eliminators in poor condition	No duct at fan discharge for velocity recovery
		Open hot water wells or basins
Water Distribution	Leaks	Stagnant water or piping that runs through unused areas
		Once-through systems used for cooling
		Use of constant speed pumps on variable loads

The site energy systems also include the distribution of the site utilities. Electricity, water, and sewer that interface with equipment remote from the site are included as are the distribution of powerhouse generated utilities. Electricity is used in all buildings and most processes. Electricity is distributed at high voltages for ease of handling and efficiency. Transformers near points of use reduce the voltage to that required by the process equipment. The efficiency of this operation is in the range of 5 to 10 percent with the loss ending up as heat. Most buildings require water; waste water is disposed through the sewer system. These systems sometimes need booster pumps to transport these fluids to their destination. Chilled and hot water distribution may also require the use of booster pumps on a large site where changes in elevation are dramatic. Site lighting is also a requirement for safety and security at night. This lighting can be accomplished by several types of lighting luminaires, each with their own cost and efficiency. Table 3 lists problems associated with these systems that result in waste or inefficiency.

Table 3. Site lighting and utility distribution.

System	Waste	Inefficiency
Electrical Distribution	Transformers oversized	Power factor less than 85%
	Transformers energized on abandoned buildings	
	Transformer taps not set at proper settings	
Water and Sewer	Heat trace equipment operating above 40 °F outside temperature	Use of high pressure pumps to service a remote location instead of use of booster pump
	Duplication or excessive metering of use	
	leaks	
	Water supply to buildings no longer in use	
Chilled and Hot Water	Duplication or excessive metering of use	Use of high pressure pumps to service a remote location instead of use of booster pump
	Leaks	Excessive heat loss/gain
	Heat trace equipment operating above 40 °F outside temperature	Flows with large variations serviced by constant speed pumps
	Water supply to buildings no longer in use	
	Unbalanced flow to users causing excessive drop through control valves.	

	Excessive bypass flow in circulating systems	
Steam	leaks	Excessive heat loss
	traps not maintained	
	Condensate receiver pumps need repair	
Compressed Air	leaks	
Site Lighting	Lights on in daytime	Use of incandescent and mercury vapor lamps
	Lighting too bright	Use of ballasts that have a high power factor
	Dirty lenses	
	Parking light operating when lot not in use	

4.2 Building Considerations

Buildings house the processes that the organization needs to carry out its goals, the people in the organization, and all the organization's assets. The building must protect the people and processes from the outdoor environment, and maintain the indoor environmental at a safe and comfortable levels. Environmental level HVAC and lighting systems are required to accomplish this. These systems interact with the building's envelope to achieve the desired conditions (Figures 7 and 8). The HVAC system requires a well insulated, reasonably airtight building structure to perform well. Windows placed in the building allows sunlight to enter, which aids the heating system, but detracts for the cooling system performance. These windows also allow natural light to enter, which reduces the need for electrically powered lighting.

An evaluation will reveal any of a number of causes of waste and inefficiencies in the HVAC and lighting system. Possible causes or problems with the HVAC system are listed in Table 4. Table 5 lists common problems associated with lighting systems.

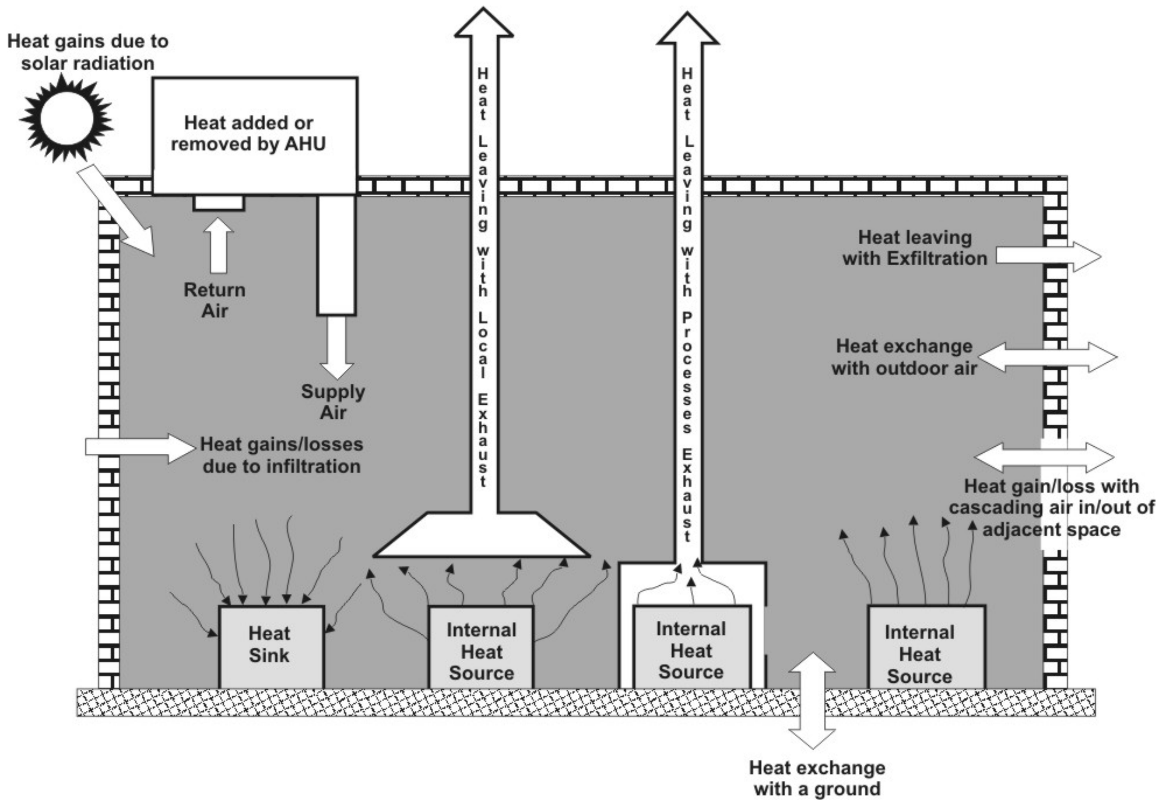

Figure 7. Building HVAC.

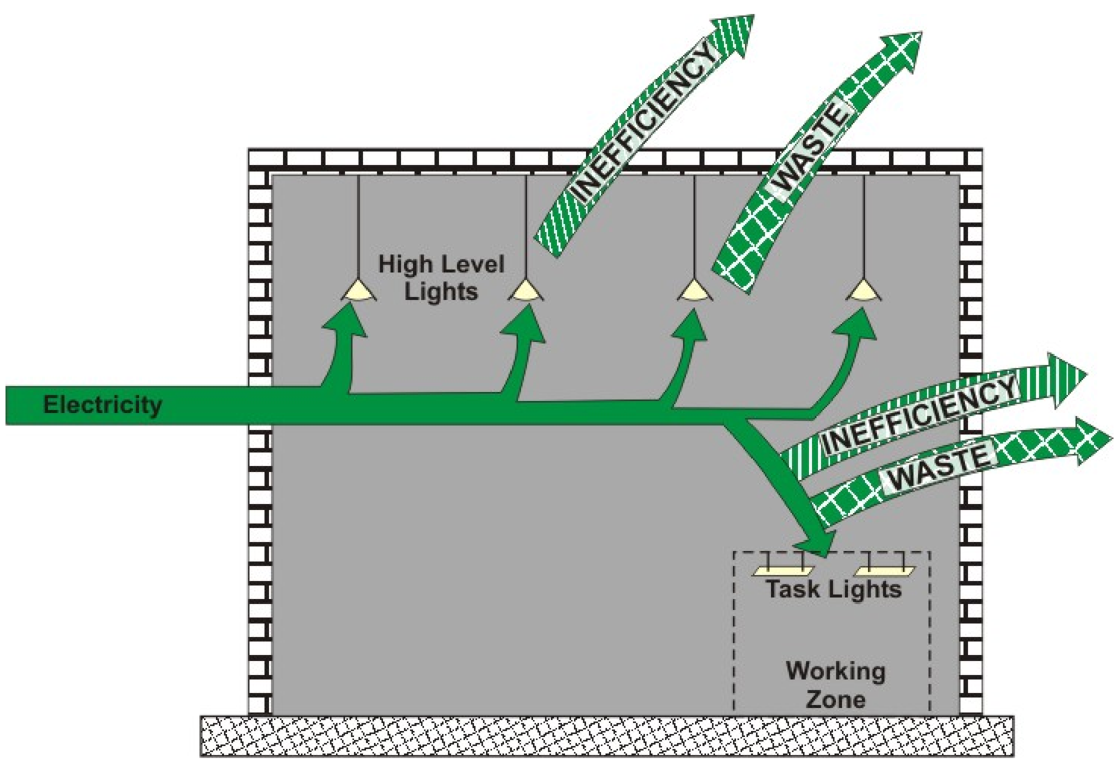

Figure 8. Building lighting.

Table 4. Causes of waste and inefficiency in building envelope and HVAC systems.

System	Waste	Inefficiency
Building Envelope	Cracks that allow outside air to enter	Cold interior walls, floor or ceiling due to inadequate insulation
	Poor moisture barriers that allow building components to become wet	Use of single pane windows without storm windows
	At doors and windows having weather-strips lacking or in poor condition	In cold climates having doors that open to outside This applies to major entrances and exits of a building
	Operable windows that do not close properly	Large clear glass windows that allows solar radiation to enter, which would affect the cooling energy use
	Doors lacking door seals	Unnecessary windows or glass walls
	Building openings or stacks that have no use	
	Broken windows, skylights and doors	
Supply Air Handling System	Inoperable, uncalibrated or poorly adjusted controls	Clean hot air/gases warmer than 200 °F being exhausted outside
	Duct air leaks	use of standard efficiency motors motors more than 2 hp that are less than 85% efficient
	Equipment operating when not needed	Use of dampers or inlet vanes to vary air flow
	Overheating or undercooling spaces	Rewinding motors more than twice
	Use of excessive dampers to achieve air balance	No winter cooling using outdoor air
	Dirty filters or coils	Use of motor two sizes greater than required
	Inoperable dampers	Use of forward curved fan blades
	Loose fan belts	Failure to reset temperature of unoccupied spaces
	No insulation on ducts or pipes warmer than 125 °F or cooler than 60 °F	Discharging condensate water to sanitary sewer rather than using it for plant irrigation, cooling tower make-up, etc.
	Frosting of the evaporator coils	Use of forced air heating in tall large tall spaces
	Heating and cooling space at same time	Temperature stratification
	Electric rehear systems	
	Heating or cooling unused spaces	
Refrigeration	No insulation on cold pipes less than 60 °F	Use of air cooled condensers
	Low refrigerant charge	Use of oversized equipment
	Frosting of the evaporator coils	

Table 5. Lighting system.

System	Waste	Inefficiency
Lighting	Excessive lighting resulting in space being too bright	Close and detailed work occurs using general lighting only
	Lighting operating when daylight is available	Use of incandescent or 40 watt fluorescent lighting in occupied spaces
	Window areas covered by curtains, shades or other non-transparent surfaces.	Use of incandescent lighting in occupied spaces
	Dirty lenses that inhibits light from reaching area of need	Use of incandescent lighting in exit signs
	Lighting operating during unoccupied time periods	Use of fluorescent lighting having magnetic ballasts
	Outdoor air lighting operating during the day time	Walls and ceiling painted dark colors that absorbs light
		High lighting power input with a little light output (the lumen per watt ratio is poor)

Common building envelope problems are:

- excessive solar gains through the roof and glazing
- drafts through cracks in building fabric (heat losses in winter and gains in summer)
- large unprotected apertures (e.g., doors) left open for traffic coming in and out of the building
- unprotected entrance doors connected to the air conditioned spaces, kept open with a human traffic entering he building before and after the shift
- poorly insulated roof, walls, large doors, single pane windows.

These problems result in energy waste for heating and cooling, health hazard in winter due to drafts and low temperature, reduced productivity due to low or high working space air temperature.

The ventilation system for the building provides fresh air for the occupants and to satisfy any process needs. Air is removed from the building to exhaust unwanted odors, process contaminants, and gases. The supply air is heated or cooled to provide a comfortable building environment. Often slightly more supply air is brought into the building than what is exhausted to provide a small positive pressure. This positive pressure reduces the amount of outside air that infiltrates into the building through cracks in the building envelope. The result is a proper building air balance (Figure 9). Table 6 lists several things to evaluate in evaluating a ventilation system for waste and inefficiencies.

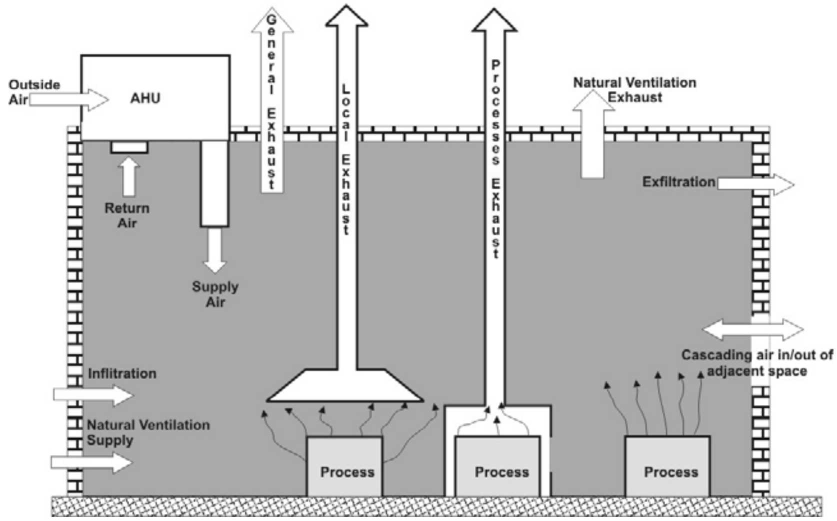

Figure 9. Ventilation system air balance.

Table 6. Ventilation system.

System	Waste	Inefficiency
Ventilation System	Use of excessive dampers to achieve air balance	Clean hot air/gases warmer than 200 °F being exhausted outside
	Loose fan belts	use of standard efficiency motors, motors more than 2 hp that are less than 85% efficient
	Equipment operating when not needed	Use of dilution ventilation in processes that could use a hood to capture the contaminants
	Air movement greater than 100 fpm near exhaust hoods	Excessive natural ventilation in winter such that cold drafts on people exist
		Use of conditioned air for hood make-up air

4.3 Building Energy Management System (BEMS)

Consider the instrumentation level and location of essential measuring points. What can one do with the existing level of instrumentation and what is needed for short-term measurements? What is the validity and performance of existing meters? Do they operate properly?

4.3.1 Industrial Processes

In industrial facilities the process operations are major energy users. Electricity is required to power electric motors. Fuels are needed in foundry, forging, heat treat, and drying operations. Heat is used in washing, cleaning and drying. Heat and cooling are required for painting, machining, and assembly. Performance of manufacturing facilities needs to consider raw materials, previously fabricated parts, labor, and added energy require-

ments when evaluating efficiency and the creation of waste. Often non-energy components of the process are much more costly than the energy used. Process activities can also affect the operation of the buildings HVAC systems. The impact needs to be considered when looking for waste and inefficiencies. Figure 10 shows the energy flows for a typical process and Table 7 lists industrial process waste and efficiency issues.

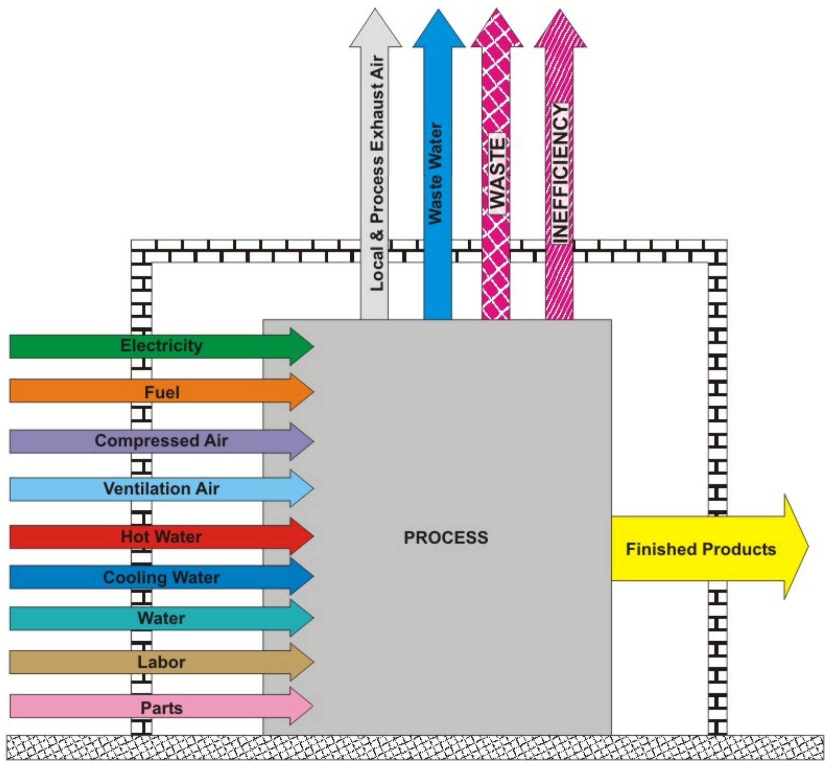

Figure 10. Industrial process energy flow.

Table 7. Process issues.

System	Waste	Inefficiency
Motors (General)	Running when not required	Use of standard efficiency motors Motors more than 2 hp that are less than 85% efficient
		Use of motor two sizes greater than required
		Rewinding motors more than twice
		Loads with large variations serviced by constant speed motors
		Use of canopy hoods to control process emissions
Heating	Heating building with only unit heaters	
Assembly	Compressed air leaks	Lack of task lighting and lighting levels greater than 30 footcandles

System	Waste	Inefficiency
Foundry	Running exhaust systems when not required.	Use of 3 hp or bigger motors having an efficiency less than 85%.
	Outside furnace temperature exceeding 125 °F	Use of oversized equipment to produce small numbers of parts
Furnace Operations	Dirty burners	Clean exhaust air warmer than 200 °F being exhausted outside.
	Improper operating dampers	More than 20% excess oxygen in flue gases
	Inoperable, uncalibrated or poorly adjusted controls	Flue gases more than 150°F warmer than leaving hot water or steam temperature
	Combustible gases in the flue exhaust	Boiler cycling on and off at low loads
	Damaged or missing refractory	Use of continuous lit pilots
	Openings used for charging too large for operation	No automatic stack damper
	Leaks around furnace doors	Use of inefficient burners
	Temperature not reduced in standby mode	Flue oil too cold for good atomization
	Use of wet and cold materials to be heated in furnaces	Heated cooling water is wasted
	Using fast melting rates during low metal demand periods	Use of underfired heaters
Heat Treat	Running exhaust systems when not required.	Use of 3 hp or bigger motors having an efficiency less than 85%.
	Outside furnace temperature exceeding 200 °F	Clean exhaust air warmer than 200 °F being exhausted outside.
	Temperature not reduced in standby mode	Use of oversized equipment to heat treat small numbers of parts
Furnace Operations	See list under Foundry Operations	Heat treat furnace having efficiency less than 65%
Machining	Compressed air leaks	Use of 3 hp or bigger motors having an efficiency less than 85%.
		Lack of task lighting and lighting levels greater than 30 footcandles
Storage	Maintaining space temperatures over 68 °F in the winter.	Lighting levels greater than 15 footcandles
Painting	Operating paint booth ventilation system when not painting	Failure to recirculate more than 70% of the oven heated air.
	Painting when part is at improper temperature	Use of high pressure spray guns
	Operating paint booths under positive pressure resulting in paint fumes in adjacent spaces	Operations that are not enclosed requiring excessive ventilation and movement of paint fumes into adjacent spaces
***Oven** Operations*	See list under Foundry Operations	

System	Waste	Inefficiency
Plating	Air movement greater than 100 fpm near exhaust hoods	Hot plating tanks have a surface temperature greater than 125 °F
	Operating exhaust systems when no planting operations are occurring and other times when not required.	Using single side exhaust hood on tanks four feet or wider.
		Exhausting clean exhaust greater than 200 °F outside
		Uncovered heated tanks over 140 °F
Welding	Operating exhaust systems when no welding operations are occurring	Using continuous operating welding exhaust
		Using stationary welding hoods
Vacuum Systems	Operating at lower pressure than required	Use of 3 hp or bigger motors having an efficiency less than 85%.
	Excessive air bleed-in through leaks	
Drying Systems	Seals in poor condition resulting in leaks	Drying equipment has surface temperature greater than 125 °F
	Equipment operating when not required	Excessive exhaust with systems that do not recirculate
	Excessive oven temperatures	
	Running equipment with part loads	
	Temperature not reduced in standby mode	
Furnace Operations	See list under Foundry Operations	

4.3.2 From Energy Source to Primary Energy Demand

This section illustrates an energy flow chain (heat generation, heat distribution, room heating system) to satisfy a heating load. It analyzes the amount of heat that must be generated and transferred to a space to satisfy the existing heat demand Qo.

Figure 11 gives the direction of the heating energy demand development in a building. Starting from the building itself, its design usage and the outdoor climate influences, one can distinguish three levels:

- the first level is the room system,
- the second level is heat distribution and
- the third level is the heat generation system.

Mechanical and energy systems cannot be implemented perfectly, so additional energy is necessary to satisfy the demand. The energy Q1 is required for the room system to satisfy the ideal energy demand Q_o. An energy efficiency factor e_i can be defined relating Q_i with Q_{i-1} ($e_i = Q_i / Q_{i-1}$).

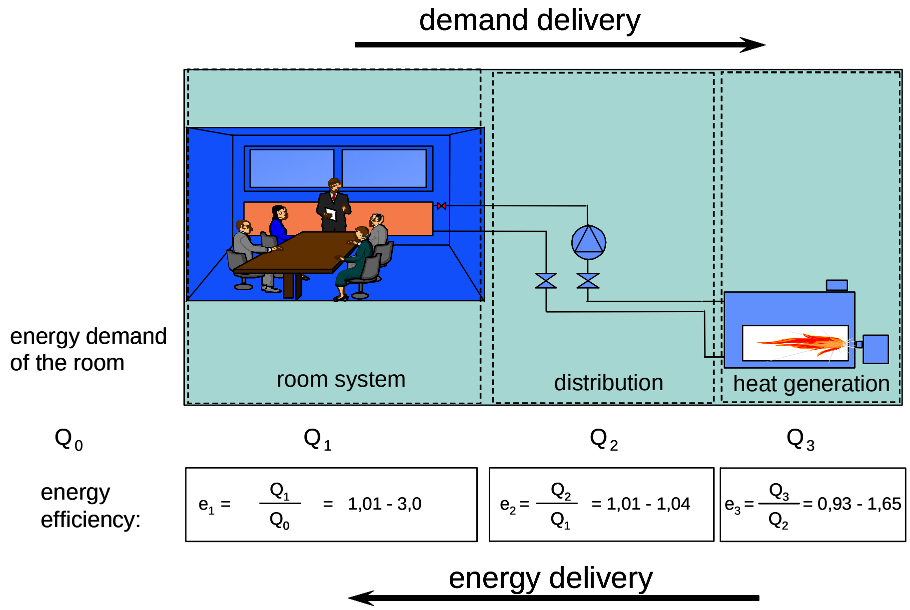

Figure 11. Energy demand and energy delivery (example for a heating load).

This parameter is used as an energy usage efficiency value to evaluate alternative technical solutions. Therefore the minimal energy demand Q0 multiplied by the energy efficiency factors e_i of each level of the energy chain gives the total yearly primary energy usage needed by the heat generation system. Figure 11 shows typical ranges of energy efficiency numbers for modern heating systems. The lower values of e_3 can be reached if heat recovery is applied. The high values of e_1 are due to inadequate operation and usage.

In most operating systems energy consumption is higher due to inefficient operation of the heating systems. Therefore, the adaptation of an existing system to the actual demand is one of the benefits of an energy audit. The described energy chain shows four areas of opportunities to reduce primary energy consumption:

3. Influence of the end-user awareness reduces Q_0
4. Adaptation of heating system operation to the actual user requirements (reduced e_1)
5. Reduction of the transmission losses (reduced e_2)
6. Optimization of the heating system that supplies the required heating energy with a minimum primary energy consumption (reduced e_3).

4.3.3 Data Collection

Identify basic ideas for energy efficiency improvements, better utilization of space and production equipment. Use checklists (see Appendix A) re-

lated to the site, buildings, processes and supporting systems, for every part of the production facility.

Collect data sheets for production equipment if available. Read data on equipment. Use drawings and production layout schemes. Make notes directly on the schemes and drawings. Measure distances, sizes and areas, preferably on drawings.

Initially, the estimation of mechanical systems includes their visual survey and check of working capacity. From interviews with the building occupants and visual survey of obvious defects in mechanical systems, the following information can be obtained:

- Are there any problems with humidity and the building envelope in the winter?
- Are there problems with the freezing through the building envelope?
- What is the air leakage through windows and doors; are there related problems with drafts?
- What are the sources of heat, electric power, water, fuel used?
- Are there problems with heating, cooling, or water supply systems, power supply, or compressed air systems?
- What are controls of mechanical systems and their technical condition?
- Are there rooms that are over- or under-heated? Are there “hot” areas with a need for cooling?
- Is the water pressure in the water supply system adequate?
- Is there urgent need in repair of mechanical systems and their elements?

During this part of assessment, the following technical documentation may be very useful:

- Drawings of a building – plans and cross-sections
- Characteristics of the building envelope elements
- Schematics of heating and ventilation, water supply, electric power and automation
- The schematic of a boiler-house
- Characteristics of the installed equipment.

The analysis of the design documentation will show if it reflects the actual facility of system conditions at the time of the audit, and if any amendments to it are needed.

4.3.4 Measuring Instruments

A Level 1 Energy Assessment requires a limited kit of basic measuring instruments, e.g., air temperature, air humidity and air velocity meters, airflow meters, infra-red surface temperature sensors, illuminance meter for lighting level measurements, flashlight, smoke-gun, measuring tape, ultrasonic distance meters, safety glasses, ear plugs, gloves, digital photo camera. They will be used during the plant tour to quantify and document the findings of the on site analysis.

4.3.5 Calculation Tools

A Level I Energy Assessment requires a limited kit of basic calculation tools, including a tool to assess the building performance, and special tools to evaluate the industrial processes. Building evaluation tools will be included in the next version of the protocol as a result of the Subtask D of Annex 46. Tools to evaluate some industrial processes and energy systems components are included on the attached CD-ROM.

4.3.6 Reporting

Executive Summary. This important part of the report should be suitable for non-technical decisionmakers (managers and financiers). It shall include brief description of the audited building, major issues and cost, and water and energy saving opportunities, with estimated cost, saving and a payback analysis, summed-up in a table of proposed Energy Conservation Measures.

Introduction and Background Information. The introduction includes the information about the audited building and housed processes, and the scope and objectives of the audit. It briefly describes the assessment methodology/protocol used, the composition of the assessment team, and acknowledges participation and support from all end users' side staff members involved in information gathering and idea generation.

Technical Documentation and Energy/Water Consumption Data. This section of the report briefly explains the main technical documents the team has obtained prior and during the assessment. Building volumes, floor areas, number of occupants, production schedule and other relevant information of the audited building shall be reported. Information on energy and water consumption (bills, metering, sub metering) and pricing shall be included. This section of the report shall also contain the

statistics concerning production levels, use of raw materials, energy, and water consumption. It's useful to include the information on the specific numbers. To compare and characterize energy consumption by similar type buildings, certain specific numbers are used. Commonly used specific numbers are: annual heat electricity and water consumption per square meter (m^2) or square foot (sq ft): kWh/(m^2* yr) and L/(m^2* yr) or Btu/(sq ft * year) and gal/ sq ft *year).

Typical specific numbers	
Heat	kJ/ (m^2* yr); kWh/ (m^2* yr);
Electricity	kWh/ (m^2* yr);
Fuel	Oil: L/(m^2* yr); Natural Gas: m^3/m^2*year
Potable water	m^3/(m^2*year)

Description of the Building. This section shall include the information on manufacturing processes and process related systems, building envelope, and mechanical/energy equipment and systems. The pre-conclusions and related results of previous studies shall be included in this section.

Results of Energy and Process Assessment. This section will include the results of interviews, assessments, and preliminary measurements organized by production and building areas. These results shall generate a list of Energy Conservation Measures/Opportunities (ECMs) with individual project "write ups." Appendix B lists examples of concept ECMs, summarized by categories that may or may not be applicable to the specific site. ECMs can range from simple non-technical measures (no-cost solutions) to those needing major investment, and possibly more detailed (Level II) assessment with a credible economic analysis and/or design:

- **No-cost/low/cost measures** require minimal investment and can often be implemented without further study. These include: general good housekeeping practices, "turn-off" campaigns, avoiding wasteful practices, adjustment of existing controls to match actual requirements of occupancy, installation of small items e.g., thermostats, insulation of sections of pipework, or fixing cracks in window frames.
- **Medium-cost measures** may require little or no further study and design and will consequently take longer to implement. The approximate range of capital cost is between $500 and $10,000 per ECM. Common investment measures include installation of new and replacement of old controls for heating, cooling or lighting, changing of lighting fixtures fro more efficient ones, insulation or refurbishment of roofs, windows, floors to reduce solar gains and drafts.

- **High cost** measures are expected to need further detailed Level II study and design. These measures may require executive level of approval before implementation. Such measures could include replacement or upgrading of plant and equipment, boilers, chillers, installation of BMS, decentralization of boiler plant or replacement it for CHP scheme.

It is assumed that the preliminary list of ECMs generated during the assessment has a buy-in (ownership even better) from the end users staff and presented to the management during the out-brief.

Considerations of ECMs relate to existing systems based on their expected remaining life time.

It is sometimes important to analyze the remaining life cycle of heating, ventilation, process and electrical systems. If the payback time of a suggested energy saving measure is long, maybe 7-10 years or more, will the system be operational that long or will it require major renovation or renewal by then? Ventilation and air conditioning systems are probably the most critical in this respect. The life time of control equipment and building automation system is 10-15 years. For fans and air handling units 20-25 years. If the system is 15 years old already, is it feasible to make improvements to improve energy efficiency or would it be better to make a larger renovation now? This decision shall be made based on the rough life cycle cost estimate based on the information obtained during the energy audit.

4.3.7 General Conclusions and Recommendations.

The main findings and descriptions of all proposed energy saving measures shall be summarized in this section of the report with the recommendations on what shall be analyzed in more detail during the Level II assessment and what and how shall be implemented right away. *The savings and investment cost analyses to be presented as tables. This section can also list the measures that were analyzed, but not recommended for implementation (that were not feasible or cost effective) with relevant calculations and explanations to "why not." Appendix C includes* an Example of the summary from a Level I assessment. Appendix D includes a recommended report structure for the Energy and Process Assessment.

5 Level II Audit

Level II analyses are characterized by more detailed measurements (submetering, temperatures, operation times, etc., preferably on an hourly basis and detailed simulations of the energy consumption by the building and its equipment.

Based on the results of the Level I analysis, the main objective of the Level II analysis is to make the energy usage more transparent, to understand selected processes better and to determine the saving goals by adapting the energy consumption to the actual energy demand of the building under its specific utilization. Thus the model used shall be able to describe the energy flows in the building (building site) in a realistic way and the measurements shall concentrate on those processes and effects that cannot be interpreted easily.

It is desirable that the synergetic consideration of measurements and calculations not be restricted to simple comparisons, and that energy saving opportunities be correlated using time dependent consumption data with other parameters like occupancy, manufacturing facility operation times or climate data.

A Level II energy audit may include the following monitoring and additional measurements:

- air flows and rate of ventilation
  - running time
  - main air flows
  - condition of the system (filters etc.)
- the efficiencies of heat exchangers (ventilation)
- measuring period of electric power (peaks and variations of the load) - the baseline test switching on/off (if possible) the main group of users
- indoor air temperatures
- outdoor air temperature and other metrological parameters
- water consumption in different areas
- occupancy
- the performance of building envelope
  - thermography – thermal bridges and insulation level
  - blower door test using own equipments (if possible) – air leaks
- pressure conditions (negative/positive pressure drops)

- automation and control system performance test-adjusting, response and balancing tests by ramp or step function test
- cooling system
- heating system
- monitoring of the performance of heating system
- utilities: water, natural gas
- Evaluation of the use of electricity based on the test and consumption distribution in some level: facilities, appliances, processes
- Industrial or other processes evaluation including the energy efficiency of the processes.

Recommendations on techniques and instrumentation for the measurement and evaluation of air infiltration in buildings are presented in Appendix E. Appendix F addresses use of thermography in building energy assessments.

A good Level II report should include energy balance calculations. Energy engineering calculations like those listed in Appendix G and on the appended CD-ROM, are used to analyze efficiencies and to calculate energy and cost savings based on improvements and changes to the building envelop, performance of heating, cooling, ventilation, air-conditioning, compressed air and other systems.

When building/site simulation model is used, energy simulation should reflect the most realistic description of the anticipated usage and energy consumption of the building/site and reflect all measured and metered quantities. The simulation results typically include:

- Calculation of the energy balance
  - multi zone model
  - hourly time resolution
  - modeling of systems and system operation
  - modeling of processes and process operation
  - realistic usage model
- Performance of the building envelope
- Performance of the ventilation system
- Performance of the heating system
- Performance of the cooling system
- Processes:
  - saving potential
  - potential for process redesign and improvement

Numerous simplified or complex models, codes, and simulation tools exist to calculate energy balances in buildings and to determine energy demand. An overview of such models and tools and practical recommendations on their application for energy audit will be given in the next edition (Version 2) of this protocol.

When planning and finalizing proposal for the energy conservation measures, especially related to industrial processes, plan meetings with the responsible personnel, building owners/facility managers to get their buy-in and understand all constrains of implementation.

The Level II audit shall also include an economic analysis of recommended ECMs. Appendix H includes “rules of thumb” for utility system ECMs.

Appendix I lists input data requirements for Life Cycle Cost analysis using the Building Life Cycle Cost (BLLC) program developed by the National Institute of Standards and Technology (NIST).

Summary and Recommendations

This work has developed a (working) version 1.0 of an energy and process assessment protocol for industrial facilities, and provided checklists for energy inefficiencies and wastes, and a consolidated list of typical energy conservation measures (ECMs). This protocol was demonstrated through showcase energy assessments at selected Army Depots and Arsenals. The results are included in a separate report (Zhivov et al. 2006).

The energy and process assessment protocol, checklists, and recommendations described and provided in this document are applied tools for industrial energy assessments and will be further developed and refined through field application and subsequent analysis. The next version of this protocol will address in greater detail different energy analysis software tools, and measurement and verification techniques to support energy assessments. It will be presented as a interactive electronic tool to allow matching inefficiencies and wastes to specific corresponding ECMs, and to simplify the analysis and decisionmaking process.

It is recommended that U.S. Army Installations tasked with meeting energy reduction goals and EPAct 2005 mandates, and those faced with increasing production and maintenance needs undertake energy assessments described here to identify energy and other operating costs reduction measures that they can implement without adversely impacting productivity, throughput, safety, morale, or the environment.

Acronyms and Abbreviations

Term	Spellout
AHU	air handling unit
AIC	Air Infiltration Center
AIVC	Air Infiltration and Ventilation Center
ANSI	American National Standards Institute
ASHRAE	American Society of Heating, Refrigerating, and Air-Conditioning Engineers
ASTM	American Society for Testing and Materials
AWS	American Welding Society
BLCC	Building Life Cycle Cost
BMS	Building Management System
BO	Building Owner
BO/OP	Building Owner/Operator
BTU	British Thermal Unit
CAV	constant air volume
CCAD	Corpus Christie Army Depot
SCF	Standard Cubic Feet
CDD	total cooling degree days
CERL	Construction Engineering Research Laboratory
CHP	combined heat and power
CIBSE	The Chartered Institution of Building Services Engineers
COP	coefficient of performance
DC	direct current
DDC	direct digital control
DHW	domestic hot water (DHW)
DOE	U.S. Department of Energy
DOE/OIT	Office of Industrial Technologies (OIT)
ECBCS	Energy Conservation in Buildings and Community Systems
ECIP	Energy Conservation Investment Program
ECM	Environmental Climate Model
EED	Emission Elimination Devices
EMCS	Energy Management Control System
EMS	Energy Management System
EPA	Environmental Protection Agency
ERDC	Engineer Research and Development Center
ERDC-CERL	Engineer Research and Development Center, Construction Engineering Research Laboratory
ES	Electrical System
ESCO	Energy Service Company
ESPC	Energy Savings Performance Contract

Term	Spellout
ETSI	Energy Technology Services International, Inc.
FCAW	Flux Cored Arc Welding
FD	Forced Draft
FEMP	Federal Energy Management Program
GMAW	Gas Metal Arc Welding
GMAW-P	Pulsed Gas Metal Arc Welding
GTAW	Gas Tungsten Arc Welding
HDD	heating degree days
HPAC	Hazard Prediction and Assessment Capability
HQIMA	Headquarters, Installation Management Agency (HQIMA)
HQUSACE	Headquarters, U.S. Army Corps of Engineers
HT	High Temperature
HVAC	heating, ventilating, and air conditioning
HW	Hot Water
IAC	Industrial Assessment Centers
IAQ	indoor air quality
ID	identification
IEA	International Energy Agency
IMA	Installation Management Agency
IR	infrared
LCC	life cycle cost
LCCA	life-cycle cost analysis
LED	light emitting diode
MCF	1000 cubic feet
MIPR	Military Interdepartmental Purchase Request
NCDENR	North Carolina Division of Pollution Prevention and Environmental Assistance
NIST	National Institute of Standards and Technology
OACSIM	Office of the Assistant Chief of Staff for Installation Management
ODUSD	Office of the Deputy Under Secretary of Defense
OIT	Office of Industrial Technologies
OP	Operator (OP)
PAW	plasma arc welding
PL	Public Law
PM	particulate matter
PRV	pressure reducing valve (PRV)
RIA	Rock Island Arsenal
RO	reverse osmosis
S/R	Supply/Return
SEER	seasonal energy efficiency ratio (SEER)
SIAD	Sierra Army Depot
SP	static pressure
SPC	Statistical Process Control

Term	Spellout
TBD	to be determined
TC	Technical Committee
TN	Technical Note
TR	Technical Report
TYAD	Tobyhanna Army Depot (TYAD)
UF	ultrafiltration
UF/RO	ultrafiltration/reverse osmosis
UIC	University of Illinois at Chicago
URL	Universal Resource Locator
USDOC	U.S. Department of Commerce
USEPA	U.S. Environmental Protection Agency
VAV	variable air volume
VFD	variable frequency drive
VSD	Variable Speed Drive (VSD)
WC	working capital fund (WC)
WWW	World Wide Web

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Appendix A: Suggested Forms To Be Used for the Level I Assessment

BUILDING CHARACTERISTICS
Building ID ___________________________________ Date of Audit:____________________
City __________________________________ State/Prov.__________________ Zip/Post____________________
Lat. ________ Long. _________ HDD_______ CDD _________ (Base 65°F) ______ (Year of Data)
Gross Floor Area, [1] ___________ sq ft Total Conditioned Area[1] ____________ sq ft
Conditioned Area, [1] heated only _______ sq ft Conditioned Area, [1] cooled only ________ sq ft
Conditioned Area, [1] heated and cooled _______ sq ft
Number of conditioned floors: Above grade _________ Below grade _________
Year of Construction[2]: __________
Brief Building Description: _____________________
PRIMARY BUILDING TYPE[3] (check one only)

Office
11 [ ] Owner Occupied
12 [ ]Leased (1-5 Tenants)
13 [ ]Leased (5+ Tenants)
19 [ ] Other—Define

Hotel/Motel
21 [ ] Motel (No Food)
22 [ ] Hotel
23 [ ] Hotel/Convention
29 [ ] Other—Define

Apartment
31 [ ] General Occupancy
32 [ ] Seniors Only
39 [ ] Other—Define

Education
41 [ ] Primary
42 [ ] Secondary
43 [ ] University
49 [ ] Other—Define

Food Services
51 [ ] Restaurant - Full Service
52 [ ] Fast Food
53 [ ] Take Out
54 [ ] Lounge
59 [ ] Other—Define

Health Care
61 [ ] Nursing Home
62 [ ] Psychiatric
63 [ ] Clinic
64 [ ] Active Treatment Hospital
69 [ ] Other—Define

Retail
71 [ ] Drycleaning
72 [ ] Supermarket
73 [ ] General Merchandise
74 [ ] Shopping Mall Without Tenant Loads
75 [ ] Shopping Mall Without Tenant Lighting Loads
76 [ ] Shopping Mall
77 [ ] Specialty Shop
78 [ ] Bakery
79 [ ] Other—Define

Assembly
81 [ ] Theatre
82 [ ] Museum/Gallery
83 [ ] Church/Synagogue
84 [ ] Arena/Gym
85 [ ] Arena/Rink
89 [ ] Other—Define

Other
91 [ ] Laboratory
92 [ ] Warehouse
93 [ ] Warehouse—Refrigerated
94 [ ] Recreation/Athletic Facility
95 [ ] Jail
96 [ ] Transport Terminal
97 [ ] Multi-Use. Complex
99 [ ] Other—Defi

1. GROSS FLOOR AREA is all floor area contained within the outside finished surface of permanent outer building walls including basements, mechanical equipment floors, and penthouses (*ANSI Standard Z65.1-1980, Construction Area*). No exclusions are made for shafts, stairs, or atria. CONDITIONED AREA is that area provided with heating or cooling to maintain temperature between 50°F and 86°F (*ANSI/ASHRAE Standard 105-1984*).
2. THE MEDIAN YEAR for construction of at least 51% of the conditioned space.
3. BUILDING TYPE as characterized by at least 51% of the conditioned space.

ENERGY PERFORMANCE SUMMARY ___________ (YEAR)

This is a summary of energy account worksheets on succeeding pages.

ENERGY TYPE	TOTAL ANNUAL USE	UNITS	CONVERSION MULTIPLIER To Thousands Btu See Page 17	THOUSANDS BTU (kBtu)	TOTAL ANNUAL COST ($)
ELECTRICITY					
NATURAL GAS					
PURCHASED STEAM					
PURCHASED HOT WATER					
PURCHASED CHILLED WATER					
OIL # _______					
PROPANE					
COAL					
OTHER					
				A	B

ENERGY AND COST INDICES

Energy Utilization Index (A ÷ Gross Floor Area) ______________________kBtu/ sq ft/yr
Cost Index (B ÷ Gross Floor Area) ___________________________________$/ sq ft/yr
Total Water Use (C) ________ kGal/yr _______or ________ft^3/yr ________$/yr
Cost Index, Including Water (B + C) ÷ (Gross Floor Area) _________________$/sq ft/yr

ANALYSIS OF METERED ELECTRICAL DEMAND

Maximum Demand _______ kW or _______ kVA ________ (month)
Maximum Demand _______ kW × 1000 ÷ Gross Floor Area = ________ W/sq ft
Minimum Demand _______ kW or ________ kVA _______ (month)
Minimum Demand _______ kW × 1000 ÷ Gross Floor Area = _______ W/sq ft

CONVERSION MULTIPLIERS
(Thousands of Btu)
(Refer to ASHRAE Standard 105-1984 for unusual fuels)

Fuel	Measured Units	Conversion Multiplier
Electricity	KWh	3.413
	MWh	3413
Natural Gas	CCF	103
	MCF	1030
	Therm	100
	Cubic Meter	36.4
	Gigajoule	947.8
Purchased Steam	1000 Btu	1.0
	1000 lb	1000
	Therm	100
Purchased Hot Water	1000 Btu	1.0
Purchased Chilled Water	1000 Btu	1.0
	Ton-Hour	12.0
Oil #2	U.S. Gallon	139
	Imp. Gallon	167
	Liter	36.7
Oil #6	U.S. Gallon	154
	Imp. Gallon	185
	Liter	40.7
Propane	U.S. Gallon	91.6
	Imp. Gallon	110
	Liter	24.2
Anthracite Coal	Ton	25,400

Water Volume Conversion

U.S. Gallons × 0.1337 = ft^3
Imperial Gallons × 0.1605 = ft^3

PRELIMINARY BUILDING USE[1]

Average Hours/Week ______________ Average Weeks/Year _____________
Average Number of Occupants During Normal Occupied Period ______________
After Hours Cleaning (y/n) _________

OVERALL BUILDING SCHEDULE

Schedule during months of _____________________________

Days	M	T	W	Th	F	Sat	Sun	Hol.
Hours Open								
Hours Closed								
Peak no. of occupants								
Avg. no. of occupants when open								

Schedule during months of ____________________________

Days	M	T	W	Th	F	Sat	Sun	Hol.
Hours Open								
Hours Closed								
Peak no. of occupants								
Avg. no. of occupants when open								

[1] Usage for at least 51% of the conditioned space.

Preliminary Energy Allocation to End Uses

Energy Type (from energy performance summary)

End Use	Primary	Secondary (more than 5% of end use)
Heating	___________	__________
Cooling	___________	__________
Domestic Water Heating	___________	__________
Kitchen Cooking Equipment	___________	__________
Laundry Equipment	___________	__________
Other Processing Equipment	___________	__________

METERED CONSUMPTION MONTHLY DATA: _________(YEAR)

Utility Company ____________________ Account #___________________ Rate Number_____________
Energy Type __________________ Consumption Units[1] ___________________
Electric Measured Demand Units[2] _________________________

Metering Period Day/Month/ Year					Electricity Only		Cost[3]		
from	to	# of Days	Consumption	"E" If Estimate	Measured Demand	Billed Demand	Consumption $	Demand $	Total $
Total									

1. CCF, therms, kWh, gal, etc.
2. kW, kVA, etc.
3. Costs should include taxes, fees, contract charges, etc.

DELIVERED CONSUMPTION MONTHLY DATA ___________ (YEAR)
Utility Company___________________ Account #_________________ Rate Number_______________
Energy Type _________________ Consumption Units[1] __________________

DELIVERY DATE	DELIVERY AMOUNT	TOTAL COST[2]
0	------------	------------
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		
11		
12		
13		
14		
15		
16		
17		
18		
19		
20		
USE OF INVENTORY	C	D
TOTAL CONSUMPTION		

1. gal, lbs, etc.
2. Costs should include tax, fees, contract charges, etc.

USE OF INVENTORY (C)

At Date 0 _____________ (A)

365 Days After Date 0 _________ (B)

Use of Inventory (A-B) ________ (C)

VALUE OF INVENTORY USED

Latest Price ________________ (D)

Value (C × D) ______________

**DETAILED USAGE SCHEDULE
(OPTIONAL)**

Usage Schedule for Each Major Space Type

Space Type
____

Schedule during months of ____________________________________

Days	**M**	**T**	**W**	**Th**	**F**	**Sat**	**Sun**	**Hol.**
Hours Open								
Hours Closed								
Peak no. of occupants								
Avg. no. of occupants when open								

Schedule during months of ____________________________________

Days	**M**	**T**	**W**	**Th**	**F**	**Sat**	**Sun**	**Hol.**
Hours Open								
Hours Closed								
Peak no. of occupants								
Avg. no. of occupants when open								

BUILDING SHELL CHARACTERISTICS

Plant / Building_______________ Date:___________

Total exposed above-grade wall area (sq ft) ___________ Insulated? Y/N

Glazing area (% of exposed wall area) ___________ Single/Double?

Roof area (sq ft) ___________ Insulated? Y/N

Floor surface area exposed to outdoor conditions (sq ft) ___________ Insulated? Y/N

Above-grade wall area common with other conditioned building (sq ft)

Construction Code	**R-Value**	**Glass Shading Coefficient**	**Area (sq ft)**

(Include miniature building floor plan, showing orientation)

Construction Type Codes

Walls
W0 = Other ______
W1 = Wood
W2 = Masonry
W3 = Concrete, Above Grade
W4 = Concrete, Below Grade
W5 = Metal
W6 = Stone
W7 = Glass
W8 = Adjacent Building

Doors
D0 = Other ______
D1 = Solid Wood
D2 = Hollow Wood
D3 = Uninsulated Metal
D4 = Metal, Insulated Core
D5 = Glass (<85%)

Roofs
R0 = Other ______
R1 = Concrete Deck
R2 = Wood Deck
R3 = Metal Deck

Windows
Sash Type
G0 = Other ______
Fixed, Wood Sash:
G11 = Single Glaze
G21 = Double Glaze
Operable, Wood Sash:
G12 = Single Glaze
G22 = Double Glaze
Fixed, Metal Sash:
G13 = Single Glaze
G23 = Double Glaze
Operable, Metal Sash:
G14 = Single Glaze
G24 = Double Glaze

Building envelope defects:

Doors / windows open ________________________________

Air locks at large entrances with slow or fast doors___________________________

Air locks/doors between departments with different climate demands____________

Doors not possible to close tightly_______________________________________

Doors with damaged weather shield_______________________________________

Opening/closing time for large doors ____

Fire hatches open____

Door closers out of order / damaged________________________________

Notices regarding simultaneous heating and cooling______________________

(e.g., unit heaters, radiators or radiant heaters in operation when doors are open)

Damages, e.g., from vehicles, on exterior wall____________________________

Ground heating, e.g., at loading docks?_______________________________

Icing problems at winter, with snow?__ __________

Check regulation ____________________

-Does ground heating switch off at temperatures above freezing point? Set value 2-3°C

-Does ground heating control consider moisture?

The following doors not closed in winter time (at on-site visit)
External sun shading in place and in use? ____________________
(Air conditioned floor space or not)

Extra unit heaters being used in winter? (Unauthorized use of heaters that employees bring themselves)____

Operation and Maintenance

Discuss/describe operation and maintenance procedures pertaining to building energy efficiency.
____
____
____
____
____
____

HVAC SYSTEM CHARACTERISTICS

Describe in detail, including floor plans and sketches.	
• Fuel Source	• Control Description and Setting
• Fuel Conversion Equipment	• Operating Periods
• Distribution Method	• Space Temperature Setting and Setback
• Terminal Type	• Operating and Maintenance Problems
• Equipment Capacity	

Heating System
____
____
____
____

Cooling System
____
____
____
____

Exhaust System(s)
____
____
____
____

Check List Heating System
Plant: __________ Year:_________

Meter no:________________

Energy use, meter readings and follow-up

Month	Energy (MWh)	Flow (m^3)	Degree days	m^3/MWh	MWh/Degr. day
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					
11					
12					

Temperature readings

Month	Outdoor Temp.	Temp room 1	Temp room 2	Temp room 3	Temp room 4	Temp room 5	“Complaints”
1							
2							
3							
4							
5							
6							
7							
8							
9							
10							
11							
12							

If needed: Further temperature analysis (S= supply R= return)

Month	**Primary (S/R)**	**Radiators (S/R)**	**Hot water (S/R)**	**Tap water Supply**	**Tap water Circulation**
1					
2					
etc.					

General:
Make notes regarding leaking heat exchangers, valves and pumps.
Noise from valves and pumps.
Pump stop function in order? (Switch off pumps when outdoor temperature > + 15 °C)
Check List Cooling Machines / Chillers

Plant:_________________Date: _________________

Location:____________ Labeled:___________________

Cooling media: _____________ Filled with (kg):__________________________

Unit serves the following areas/processes/machines:________________________

Service reports /Journal

Last service, date:_____ ______________ Report no:____________

Notes in report/journal: (Passed, leakage, contamination, cleaning…)
____
____
____

Controls

What controls the unit: (External signal e.g., from ventilation, room thermostat… or internal control of set point for constant supply temperature)
____
____

Set points, per machine and system: ____ °C

Remarks:____

Suggested savings: Better controls, free cooling, changed set points, heat recovery, etc.

Check List Lighting

Plant/department_____________Date__________

Room/part of plant_____________ Floor space ______m^2

Working hours____

Type of lighting ____

Installed: W/m^2_____________________________ (count fixtures and bulbs, check total watts per fixture, incl. ballasts)

Average installed load including ballast in more than 51%___________W/m^2 of occupied space
Switches Accessible to more than 51% of occupants ________ Y/N?
Special Automatic Controls ________ Y/N?

Major Lighting Types 1 = Fluorescent 2 = Incandescent 3 = Mercury Vapor 4 = Sodium 5 = Metal Halide 6 = Other	% of Occupied Area

Recommendations installed	W/m^2
Small offices ($<10m^2$)	<12
Large offices ($>10m^2$)	<10
Corridors, up to 3m height	<6
Industrial premises (300 Lux)	$<6,6$

Measured lighting level, Lux?____

Are operating hours for lighting adapted to working hours?
____

Outdoor lighting switched on at daytime?_____________________________

Task lighting installed? Describe____
Lighting controls exist? ____
Does it function properly?____

Occupancy sensors?________________
Day light control?_________________________________ Turn on at Lux______________
Time schedule in use?_____________________________Operating hours______________

Remarks:____

Check List Machines and Processes

Plant/dept_____________ Date____________

Working hours /shifts, weekdays:____
Working hours /shifts, weekends:____
No. of machines in dept (regularly used) / % of total floor space used:_____________
____

Planned changes in production layout:____

Machines/processes that are not switched OFF during non-production hours:
____
____
____
____

Parts of machines/processes that are running although machine is switched off:
____
____
____
____
____

Identified compressed air leakage (machine, location)
____

Chillers running for electronics cabinet_____________ Set point temp:______°C

Process vent running when machine OFF____
Operating hrs, process vent (timer or time schedule): Mon –Fri:__________________
Sat – sun:______
Surface temperature, hot processes/tanks:____
____

Temperature requirements for processes:______________________________________

Primary energy use per machine/process (Steam, HW, electricity/gas):________________
____

Process cooling, describe:____

Cooling provided from (central system, separate chiller….)__________________________

Check List Responsibilities: Owner/Operator/Contractor

Building /plant: _______________

Building owner:____(BO)
Operator (who runs production):_______________________________(OP)

ESCO (Contractor):____(ES)

Describe existing contracts:
_________________________________ valid due______________
_________________________________ valid due_______________
_________________________________ valid due______________

Who pays the energy bills:

		BO	OP	ES
Electricity				
Coal/oil/gas/distr. heat				
Water				
External cooling				
Who controls energy bills (BO/OP/ES, name)?	Name:____________________ ______________________			
Who takes care of:				
Lighting	Changing bulbs/fluor. tube			
	Other maintenance			
	Oper. Hours/controls			
	Investments when retrofit.			
Ventilation	Filter changes			
	Periodical maintenance			
	Function checks			
	Oper. Hours/controls			
Building envelope	Doors, function			
	Tightenings/air locks			
	Maintenance			
Cooling machines	Oper. Hours/controls			
	Maintenance			
Air compressors	Oper. Hours/controls			
	Maintenance			

If Building owner or ESCO runs support systems the following should be delivered to Operator at least monthly:
Energy reports
Settings in control systems (Operating hrs, temperatures, lux levels etc.)
Service reports and protocols
Identified faults that need action

Check List Ventilation

Air Handling Unit:______________ Serving (area): _________________________
Location: ______________________________________
Operating **hours**: Mon – Fri:____ Sat – Sun:______**(or other time schedules)**

Heat recovery?__________________Type:_________________
Primary energy to heating coil
(el./steam/HW/gas):____________________________________

Timer for manual overtime? ____________________ Does it work?_________________

Production hours the same as AHU operating hours?_____________________________
Are there different operational modes?
___________________________________(describe)
VFD?____
Heat recovery: _______________Room temp. regulation:_________________________
Temperatures

Quarter	**Supply Temp**	Room Temp	**Exhaust air Temp**	**Outdoor air Temp**
1				
2				
3				
4				

Calculate efficiency: (Supply – Outdoor) / (Exhaust – Outdoor) x 100 = Heat exchanger efficiency

Supply air temperature is temperature after heat exchanger, but before heating coil. Exhaust air is after heat exchanger. Efficiency only possible to calculate when heating need is substantial.

Quarter	Efficiency		
1			
2			
3			
4			

Guidelines efficiency	
Cross flow	60%
Liquid flow circulating	50%
Rotating wheel	80%

General:
Check set point for supply air temperature.
Check if coils, fan house and air intake is contaminated

Notice: leaking valves and pumps. noise from belts, drives etc.
Read or measure pressure drop over filters.

INVENTORY OF MAJOR HVAC EQUIPMENT

This table format is intended as a guide. The information collected on systems need not be restricted to the format or categories below.

Designation	Location	Model/ Type	Size	Capacity	Serves	Operating Hours/Year	Remarks

DOMESTIC HOT WATER SYSTEM CHARACTERISTICS

Describe in detail:	
• Fuel Source • Storage • Hours Operated	• Distribution • Setpoints • Hours Required • Circulating Pump

Domestic Hot Water System

____

____

____

____

ENERGY ANALYSIS SUMMARY

Building ID ____

Date of Audit Month ___________ Year __________

		kBtu sq ft /yr	$/ sq ft /yr	$/yr
Actual Use	A			
Target[1]	B			
“Technical” Potential Savings	C (A-B)			
Savings from Measures Recommended for Implementation (see attached)	D			
Remaining Technical Potential Savings to be Defined	E (C-D)			
Realistically Achievable Potential Savings still to be Defined	F			
Total Achievable Savings	(D+F)			

Cost of Next Stage in Analysis $ ________ (G)

Cost of Measures Recommended (D) $ ________ (H)

Cost to Implement Potential Savings Still to be Defined (F) $ ________
(±_____ %)(I)

Total Implementation Cost (G+H+I) $ ________

1. Source:
____
____

COMPONENTS OF ANNUAL ENERGY USE

	Electricity		Fuel	Other	Total	% of Total	Total	% of Total
	kWh	kBtu	kBtu	kBtu	kBtu	Use	Cost	Cost
Space Heating								
O.A. Heating								
Space Cooling								
O.A. Cooling								
Fans								
Pumps								
DHW Generator								
Lighting Within Conditioned Area								
Outside Condi-tioned Area								
Receptacles								
Kitchen								
Laundry								
Central Computer								
Conveyance								
Laboratory Equipment								
Other (describe)								
Unaccounted								
TOTAL						100%		100%

RECOMMENDED ENERGY CONSERVATION MEASURES

Measure Description	Energy Type(S)	Units Saved	$/Year Saved	Implementation Cost	Extra Oper. + Maint. Cost	Simple Payback (Years)
1.						
2.						
3.						
4.						
5.						
6.						
7.						
8.						
Total if all measures implemented						

Appendix B: Some Energy Conservation and Process Improvement Opportunities with a Focus on Industrial Facilities

1	General Process Improvement
1.1	Reduce operating cost by optimizing the process
1.2	Reduce cost of product or service by eliminating waste
1.3	Optimize maintenance costs to increase capacity utilization
1.4	Increase process throughput by reducing cycle times
1.5	Optimize yields by reducing off-specification product
1.6	Reduce scrap/wastage/breakage by modifying the process causes
1.7	Reduce rework by not taking short cuts that make rework
1.8	Reduce downtime by optimizing planning and scheduling
1.9	Improve product quality by improved process control
1.10	Improve repeatability/consistency by using Statistical Process Control (SPC)
1.11	Improve safety by thinking about the safest way before starting
1.12	Reduce pollution/hazardous waste by modifying the processes that cause it
1.13	Reduce labor cost by optimizing labor use
1.14	Optimize overtime by analyzing the causes and correcting them
1.15	Simplify processes by eliminating unnecessary, non-value added steps
1.16	Reduce number of process steps by questioning and challenging their value
1.17	Improve tooling/fixtures/jigs to increase capacity use
1.18	Improve working conditions to improve productivity by increasing building ventilation
1.19	Reduce work hours/day or days/week by working on the important things
1.20	Improve process specifications/documentation to treat continuous improvement
1.21	Reduce inspections without reducing quality by eliminating unnecessary inspections
1.22	Optimize inventory by optimizing procurement/logistics
1.23	Improve tools to increase productivity and product quality
1.24	Simplify inspections by eliminating unnecessary requirements
1.25	Encapsulate process to reduce indoor air contaminating emission
1.26	Change the process by replacing materials with lower contaminant emission materials when possible
1.27	Increase accuracy, timeliness, applicability, and usefulness of the inspection by optimizing the inspection processes.

2	Process Control
2.1	Energy Management Control System (EMCS) installation, replacement, and alteration
2.2	Install demand limiting control system
2.3	Install duty cycling control system
2.4	Install economizer cooling control system
2.5	Install hot/chilled water supply temperature reset control systems
2.6	Install supply air temperature reset control system
2.7	Install temperature setup/setback control system
2.8	Install time of day control system
2.9	Install ventilation purging control system
2.10	Install single building controllers (DDC)
2.11	On/off controls (electronic time clocks)
2.12	Install temperature control valve to reduce flow when not developing
2.13	Reduce flow to manufacturer's specifications for actual operating conditions
2.14	Install solenoid valve to shut-of rinse and cooling flows when product is not being developed
3	Specific processes
3.1	Painting
3.1.1	Recycle water used to collect overspray paint by treating water with dissolved air flotation and filter dewatering system to separate toxic solids
3.1.2	Install heat recovery from paint process. 40 to 60% of heat input is vented through the exhaust from painting process, while additional heat is lost as waste heat through the walls Heat recovery in paint process, therefore can be significant. However, some of this heat recovered from the stack is low grade heat. If the problem of tar contamination can be overcome, heat can be recovered from the stack. Heat can be recovered using heat wheels or other technologies
3.1.3	Maintain optimal air temperature and relative humidity for faster drying and to eliminate rework due to defects in the coating. These parameters depend upon the paint process and type of paint used.
3.1.4	Install VFDs on exhaust and supply fans connected to the sensor installed on the compressed air line to the paint gun. VFDs allows reduction of exhaust and supply air into the paint booth when there is no paint spraying. Reducing the volume of air put through paint booth also limits the amount of energy to treat the supply and exhaust air.
3.1.5	Use infrared paint curing. Infrared ovens replace gas-fired low-bake ovens to speed up the stoving process. Infrared process reduces energy consumption by reducing paint booth size and increases productivity by reducing stoving time.
3.1.6	Use ultrafiltration/reverse osmosis (UF/RO) for wastewater cleaning. When the water-based paint is used, processing equipment must be regularly cleaned with water. A typical painting operation requires significant amount of water to clean, all of it must be disposed of as hazardous waste Reducing this hazardous waste, therefore reduces transportation and incineration energy associated with its removal. A combined UF/RO process cleans wastewater to the point where it is again suitable for cleaning purpose. The UF/RO can recover 95% of the waste water.
3.1.7	Insulate the drying booth or tunnel. Insulation of the drying booth or tunnel can reduce the heat losses through irradiation, which can be about 5% of the total energy input.
3.1.8	Fix badly functioning entry and exit doors of drying booths, which can cause additional heat losses

3.2	**Plating And Metal Finishing**
3.2.1	Install emission "elimination" cover on Cr tank and reduce exhaust air flow rate when the tank is covered
3.2.2	Control exhaust airflows and steam heating on plating tanks
3.2.3	Insulate plating tanks with the surface temperature above 49°(120°F)
3.2.4	Treat rinse water to recover valuable metals or chemicals to return to plating bath, with clean water returned to rinse system
3.2.5	Rinsing and cleaning - install timers and tamper-proof conductivity controllers to control quality of water in rinses
3.2.6	Rinsing and cleaning - install ultrasonic cleaning equipment
3.2.7	Rinsing and cleaning - install water-saving technologies or modification that are specifically geared toward each facility. Examples are counter-current rinsing, drag-out tanks or first stage static rinses, spray systems, flow reduction devices
3.2.8	Use no-mask anode tooling technology to reduce labor cost, plating time and the amount of time needed to grind the surface after plating. Reduction in plating time results in increased throughput and reduced energy consumption (for tank heating and cooling and exhaust air transportation and scrubbing)
3.3	**Welding**
3.3.1	Select welding process that produces the least volume of fume consistent with other application considerations. GTAW, plasma arc welding (PAW), and SAW processes generally produce the lowest fume levels. GMAW is normally the process with the next lowest fume generation rate.
3.3.2	Use high efficiency welding power sources, which have better electrical efficiency and an improved power factor. In high efficiency welding, power to the transformer is shut off during system idling and cooling fans only run when needed. These power sources provide 10 to 40%energy savings over older units.
3.3.3	Use modern inverter welding power sources, which can reduce the fume generation for pulsed gas metal arc welding (GMAW-P) compared to conventional GMAW procedures.
3.3.4	Selecting optimum welding voltage to reduce fume generation.
3.3.5	Select welding electrodes with reduced fume generation. Electrodes and electrode coatings containing higher percentages of more volatile ingredients produce higher levels of fume.
3.3.6	Select shielding gas with reduced fume generation for the GMAW and Flux Cored Arc Welding (FCAW) processes. Argon-based shielding gases with the lowest percentages of oxygen or carbon dioxide will minimize fume for both GMAW and FCAW. The fume generation rate can be cut almost in half by changing from 100 percent CO_2 shielding gas to a mixture of Argon with 25 percent CO_2 shielding gas. A further reduction in fume generation rate can be achieved by use of a shielding gas containing Argon with only 5% CO_2 along with the appropriate electrode.
3.3.7	Avoid, remove, or reduce oil film, paint, primer, rust, galvanizing or other coatings on the welded surfaces since these coatings increase fume.
3.3.8	Reduce expulsion during spot welding
3.3.9	Avoid short-time conditions with spot welding, changing over to medium-time conditions
3.3.10	Place containers with welded small parts in the totally enclosed cabinets connected to exhaust system to avoid residual welding smoke release into the building.
3.3.11	Exhaust from the total welding process enclosure when automatic welding machines are used
3.3.12	Exhaust from the welding area enclosure separating welding process from operator's environment , when robotic welding and material handling are used,
3.3.13	Install local exhaust, which captures the contaminants at or near their source, with manual and

	semiautomatic welding operations
3.3.14	Use built-in fixture exhaust system for repetitive arc and resistance manual and robotic welding operations. An engineered design to reduce exhaust air volume, increase capture effectiveness of fumes generated during and after welding operations. Requires co-operation of process and ventilation engineers.
3.3.15	Install demand based exhaust system for weld fumes control in shops with variable work load and welding processes with duty cycle below 70%
3.4.	14.6. Catering facilities
3.4.1	Food storage. Locate refrigerators and freezers away from heat sources, Minimize frequency of opening refrigerators and freezers. Never put hot food in refrigerators. Adopt a planned defrosting program. Check door/lid seals and replace as necessary. Replace old equipment with new efficient models. Install motor controls to improve compressor efficiency at low loads.
3.4.2	Food cooking and serving. Minimize preheating time for ovens, fryers and other equipment. Switch off ovens before the end of the cooking time. Minimize hot storage of cooked food. Keep hot plates and gas burners clean. Introduce regular servicing of cooking appliances, including thermostats and automatic timers. Install energy efficient and effective cooking appliances. select induction hobs. Select equipment sizes appropriate to task. Consider batch cooking to optimize use of cooking appliances. Install microwave ovens to cook and reheat meals.
3.4.3	Air extraction equipment. Install energy efficient ventilation hoods. Locate hoods directly over ovens, fryers, and grills, which need air extraction. Coordinate layout of kitchen hoods and ductwork with cooking equipment layout and process. Switch on extract systems only when required and switch off as soon as possible. Clean filters, grills and fan blades regularly to prevent grease build-up. Close external doors when operating extract fans.
3.4.4	Use water conserving dishwashers
3.4.5	Install gray water heat recovery
3.5.	Swimming pool
3.6.1	Cover swimming pool when pool is not in use, e.g., lunch time, after hours to save both water and energy (heating, cooling and electrical energy saving.) On external pools can save 80% of energy costs.
3.5.2	Check the water temperature (shall not be above 27 °C (81°F)
3.6.	Photo and X-ray processing
3.6.1	Install temperature control valve to reduce flow when not developing
3.6.2	Reduce flow to manufacturer's specifications for actual operating conditions
3.6.3	Install solenoid valve to shut-of rinse and cooling flows when product is not being developed

4	Steam System
4.1	Check steam trap sizes to verify they are adequately sized to provide proper condensate removal
4.2	Consider opportunities for flash steam use in low temperature processes
4.3	Consider pressuring atmospheric condensate return systems to minimize flash losses
4.4	Consider relocation or conversion of remote equipment such as steam-heated storage
4.5	Evaluate insulation of all uninsulated lines and fittings previously thought to be uneconomic
4.6	Evaluate potential for cogeneration in multi-pressure steam systems presently using large pressure-reducing valves
4.7	Evaluate production scheduling of batch operation and revise to minimize startups and shutdowns
4.8	Implement regular steam leak survey
4.9	Install condensate return system
4.10	Install cross connect lines on steam distribution systems
4.11	Install insulation on steam distribution systems
4.12	Install steam metering and monitoring systems
4.13	Investigate economics of adding insulation on presently insulated lines
4.14	Review mechanical standby turbines presently left in the idling mode
4.15	Review operation of long steam lines to remote single-service applications
4.16	Review operation of steam systems used only for occasional services, such as winter-only tracing lines
4.17	Review pressure-level requirements of steam-driven mechanical equipment to consider using lower exhaust pressure levels
4.18	Review requirements of heated storage vessels and reduce to minimum acceptable temperatures
4.19	Survey condensate presently being discharged to waste drains for feasibility of heat recovery
4.20	Check flue for improper draft
4.21	Us e primary/secondary pumping configurations on central plants
4.22	Reclaim heat from steam condensate
4.23	Maintain steam traps
4.24	Reduce water or steam flow rates in pipes
4.25	Remove scale from water and steam pipes
4.26	Repair steam system controls
4.27	Consider replacement of steam distribution system with a hot water system to reduce heat and water losses, and reduced cost of replacement piping

5 Heating System/Boilers	
5.1	Install air-atomizing burners for oil-fired boiler systems
5.2	Install automatic boiler blow-down control
5.3	Install automatic vent dampers on boilers
5.4	Install flue gas analyzers for boilers
5.5	Install an automatic flue damper to close the flue when not firing.
5.6	Install turbulators to improve heat transfer efficiency in older fire tube boilers.
5.7	Install low-excess-air burners
5.8	Install condensing economizers
5.9	Install electric ignitions instead of pilot lights.
5.10	Install an automatic combustion control system to monitor the combustion of exit gases and adjust the intake air for large boilers.
5.11	Isolate off-line boilers
5.12	Maintain insulation on heat distribution system. Replace insulation after the system repair
5.13	Provide proper water treatment to reduce fouling
5.14	Replacement of central plant with distributed satellite systems
5.15	Replacement of satellite boilers with central plant
5.16	Downsize boilers with optimum burner size and Forced Draft (FD) fans
5.17	Shut down large boilers during summer and use smaller boilers
5.18	Upgrade of natural gas-fired boilers with new controls (low NOx burners)
5.19	Check expansion tank sizes on hot water systems
5.20	Heat recovery through de-superheating
5.21	Install booster pumps on hot water systems
5.22	Preheat feedwater with reclaimed waste heat
5.23	Provide for avoiding artificial loading (hot gas bypass at low loads)
5.24	Preheat combustion air, feed water or fuel oil with reclaimed waste heat
5.25	Reclaim heat from boiler blowdown
5.26	Reclaim heat from combustion system flue
5.27	Reclaim heat from prime movers
5.28	Reclaim incinerator heat
5.29	Use hot water from boiler condensate to preheat air.
5.30	Boilers - capture steam condensate for reuse
5.31	Boilers - install automatic controls to treat boiler make-up water
5.32	Adjust boilers and air conditioner controls so that boilers do not fire and compressors do not start at the same time, but satisfy demand.
5.33	Check flue for improper draft
5.34	Clean boiler surfaces of fouling
5.35	Replace and resize boilers for efficiency
5.36	Shut down large boilers in summer and use small ones when possible
5.37	Replace non-condensing boilers with condensing boilers (15-20% compared to new standard)
5.38	Prevent dumping steam condensate to drain

5.39	Survey and fix steam/hot water/condensate leaks
5.40	Convert steam system to low temperature sliding temperature hot water system. Install complementing steam boilers where needed
5.41	Survey and replace failed steam traps
5.42	Reduce excess air. Poorly maintained boilers can have up to 140% excess air. Reducing the excess air down to 15% (required for safety) can increase boiler efficiency by 1% for each 15% reduction of excess air or 40oF (22 °C) reduction in stack gas temperature.
5.43	Use smaller boiler when possible to operate below full load, e.g., install smaller boilers for summer operations and to supplement winter operations.
5.44	Improve boiler insulation. It is possible to use new materials that insulate better and have lower heat capacity. Savings of 6-26% can be achieved if this improved insulation is combined with improved heater circuit control. Several case studies estimate an average payback period for this measure of about 11 months.
6	Cooling System/Chillers
6.1	Chiller retrofits
6.2	Cooling tower retrofits including high efficiency fill, VSD fans, fiberglass fans, hyperbolic stack extensions, fan controls, VSD pump drives, and improved distribution nozzles
6.3	Install economizer cooling systems
6.4	Install evaporative pre-cooling on 100 percent make-up air
6.5	Install evaporative cooled or water cooled condensers
6.6	Install evaporative cooling systems with or without a heat pipe
6.7	Install roof-spray cooling systems
6.8	Insulate low side refrigerant lines
6.9	Investigate use of gas engine driven chillers
6.10	Isolate off-line chillers and cooling towers
6.11	Reduce ammonia head pressure
6.12	Reduce over pumping on chilled water systems
6.13	Reduce non-condensable gases in refrigerant systems
6.14	Replace absorption with electric drive chillers
6.15	Resize chillers
6.16	Retrofit with higher coefficient of performance (COP) equipment
6.17	Stage multiple chillers
6.18	Use of absorption to reduce electric demand
6.19	Use gas absorption chillers where appropriate
6.20	Install double bundle chillers
6.21	Install piggyback (absorption systems)
6.22	Reclaim heat from refrigeration system hot gas
6.23	Equipment cooling, control make-up water and reduce blowdown by adding temperature control valves to cooling water discharge lines in equipment such as air compressors and refrigeration systems
6.24	Evaporative cooling systems - consider side stream softening for very large cooling loads
6.25	Evaporative cooling systems - install drift eliminators or repair existing equipment

6.26	Evaporative cooling systems - install softeners for make-up water; side stream filtration (including nano-filtration, a form of low-pressure reverse osmosis); and side stream injection of ozone
6.27	Evaporative cooling systems - install submeters for make-up water and bleed-off water for equipment such as cooling towers that use large volumes of water
6.28	Evaporative cooling systems control cooling tower bleed-off based on conductivity by allowing bleed-off within a high and narrow conductivity range. This will achieve high cycles of concentration in the cooling system and reduce water use in cooling tower
6.29	Use existing cooling towers to provide chilled water instead of using mechanical refrigeration for part of the year.
6.30	Clean evaporator and condenser surfaces of fouling
6.31	Raise evaporator or lower condenser water temperature
6.2	Optimize chiller sequencing
6.33	Use two-speed or variable-speed fan instead of water bypass to modulate the cooling tower capacity
7	Building Envelope
7.1	Use “cool roof” (high reflectance roofing material) with reroofing projects
7.2	Caulk and weather-strip doors and windows
7.3	Determine roof insulation values and recommend roof insulation as appropriate
7.4	Replace single pane and leaky windows with thermal windows to minimize cooling and heating loss.
7.5	Install exterior shading such as blinds or awnings to cut down on heat loss and to reduce heat gain.
7.6	Install interior shading
7.7	Install local ventilation systems for hot areas (vice central ventilation system)
7.8	Install operable windows
7.9	Add revolving doors or construct vestibules at primary exterior personnel doors
7.10	Install automatic doors, air curtains, strip doors, etc. at high-traffic passages between conditioned and non-conditioned spaces. Use self-closing doors if possible.
7.11.	Install vestibules/airlocks for large doors at vehicle entrances/loading areas
	Install doors/seals in loading dock areas
7.12	Install high-speed doors between heated/cooled building space and unconditioned space in the areas with high-traffic passages
7.13	Install separate smaller doors for people near the area of large doors for vehicles
7.14	Install storm windows and multiple glazed windows
7.15	Install vapor barriers in ceilings and roofs
7.16	Install vapor barriers in walls
7.17	Insulate ceilings, roofs, floors, and walls using spray-on insulation
7.18	Insulate floors
7.19	Insulate walls. Retrofit insulation can be external and internal. External post insulation makes large savings possible, as this type of insulation contributes not only to a reduction of the heat loss through large wall surfaces, but also eliminates the traditional thermal bridges where floor and internal wall are anchored in the exterior wall. Internal insulation is typically done when external insulation is not allowed (e.g., for historical buildings). Internal post-insulation is usually done by mounting lathes on the inside of an existing construction. Insulation material is placed between the lathes and gypsum boards, wood or

	other finishes. Internal post insulation may involve a risk of defects in the construction caused by moisture, as the resulting moisture resistance of the vapor barrier is required to be significantly higher than that of the original construction. Besides the insulted space cannot be used as long as the work is in progress and the inner room measurements are reduced.
7.20	Prevent heat loss through doors by draft sealing and thermal insulation. The potential heat loss due to air infiltration is however far higher than due to poor thermal insulation.
7.21	Seal vertical shafts and stairways
7.22	Use tinted or reflective glazing or films
7.23	Weatherization/fenestration improvements
7.24	Consider replacing exterior windows with insulated glass block when visibility is not required, but light is required,
7.25	Install windbreaks near exterior doors
7.26	Use reflective solar window tinting
7.27	Landscape/plant trees to create shade and reduce air-conditioning loads
7.28	Exhaust hot air from attics
7.29	Keep doors of air conditioned spaces closed when HVAC system is running.
7.30	Use physical barriers on industrial loading bays single door to outside during cold and hot weather. The physical barrier consist of overlapping heavy plastic or rubber flaps that have to be physically moved aside.
7.31	Install air curtain on a single external door where space restrictions or other considerations result in a single external door. Use tempered (heated or cooled) air jets or unheated/uncoiled indoor air curtains to prevent cold/hot air from entering.
7.32	Install/repair brush seals on revolving or single external doors
7.33	Reduce operating hours of complementing heating and cooling systems (e.g., hydronic)
8	Building HVAC System
8.1	Chilled water temperature reset
8.2	Consolidation of existing HVAC equipment in either an existing building or group of buildings
8.3	Provide cooling effect by creating air movement with fans
8.4	Duty cycling for demand control
8.5	Eliminate or downsize existing HVAC equipment in either an existing building or group of buildings by improvements in building envelope; reductions in lighting or plug loads; etc.
8.6	Use high efficiency fans and pumps with replacing existing ones or trim impellers of existing ones
8.7	Free cooling cycle by piping chilled water to condenser during cold weather
8.8	Install air cleaners in HVAC system
8.9	Convert a constant air volume system (CAV) into a variable air volume system (VAV) with variable speed drives on fan motors. A VAV system is designed to deliver only the volume of air needed for conditioning the actual load.
8.10	Install modular HVAC units
8.11	Insulate HVAC ducts
8.12	Insulate HVAC system pipes
8.13	Night setback or turning off HVAC equipment when building is unoccupied Reduce HVAC operating hours to reduce electrical, heating and cooling requirements. Eliminate HVAC usage in vestibules and unoccupied space.

	Minimize direct cooling of unoccupied areas by turning off fan coil units and unit heaters and by closing the vent or supply air diffuser. Turn fans off. Close outdoor air dampers. Install system controls to reduce cooling/heating of unoccupied space.
8.14	Create building/air conditioned space zones with separate controls.
8.15	Reduce air flow rates in HVAC ducts when possible
8.16	Use high efficiency electric motors when replacing existing motors
8.17	Replace forced air heaters with radiant heaters
8.18	Replace indirect fired heaters with direct fired heaters
8.19	Replace inefficient window air-conditioners with high seasonal energy efficiency ratio (SEER) units
8.20	Variable speed drivers for fans and pumps
8.21	Replace window air conditioning with central system
8.22	Conversion of electric heaters to natural gas radiation/convection
8.23	Install geothermal space and water heating
8.24	Check for air leaks in HVAC system
8.25	Clean air filters in ducts
8.26	Lower heating and raise cooling temperature setpoints when the area is too hot or too cold
8.27	Lower hot water temperature and development of peak-shaving strategies
8.28	Lower humidification and lower hot water temperature
8.29	Lower humidification and raise dehumidification setpoints
8.30	Rebalance ducting systems
8.31	Rebalance piping systems
8.32	Reduce HVAC operating hours for space heating, cooling and ventilation. Turn HVAC off earlier. Install HVAC night-setback controls. Shut HVAC off when not needed. Adjust thermostat settings for change in seasons. Adjust the housekeeping schedule to minimize HVAC use. Schedule off-hour meetings in a location that does not require HVAC in the entire facility. Install programmable zone thermostats Install local heating/cooling equipment to serve seldom-used areas located far from the center of the HVAC system. Install controls to vary hot water temperature based on outside air. Use variable speed drives and direct digital controls on water circulation pumps motors and controls.
8.33	Reduce operating hours of complementing heating and cooling systems (e.g., hydronic)
8.34	Install an economizer cycle. Instead of operating on a fixed minimum airflow supply, an economizer allows the HVAC system to utilize outdoor air by varying the supply airflow according to outdoor air conditions, usually using an outdoor dry bulb temperature sensor or return air enthalpy (enthalpy switchover). Enthalpy switchover is more efficient because it is based on the true heat content of the air.
8.35	Minimize exhaust and make-up (ventilation) rates when possible. Makeup air rate depends on the needs of ventilation for personnel, exhaust air from workspaces, overcoming infiltration, machine air needs, and federal, state and local requirements.

8.36	Employ heat recovery from exhaust air and processes for the supply air treatment. Common types of heat exchangers are: rotary, sealed, plate, coil run-around system, and hot oil recovery system. Depending upon the equipment used, heat recovery efficiency can vary between 50 and 70 percent..
8.37	Repair (seal) supply and exhaust ducts and piping leaks. Up to 20 percent of conditioned air can be lost in supply duct run.
8.38	Reset supply air temperatures
8.39	Rewire fans to operate only when lights are switched on, as codes permit and when possible.
8.40	Use operable windows for ventilation during mild weather when available.
8.41	Eliminate reheating for humidity control (often air is cooled to dewpoint to remove moisture, then is reheated to desired temperature and humidity).
8.42	Shut off unneeded exhaust fans and reduce use where possible.
8.43	Check for damper leakage/ensure tight seals.
8.44	Evaluate thermostat controls and location. Install programmable thermostats. Lock thermostat to prevent tampering. Ensure proper location of thermostat to provide balanced space conditioning. Avoid the proximity of the heated or cooled air producing equipment to thermostat.
8.45	Implement an energy management system (EMS) designed to optimize and adjust HVAC operations based on environmental conditions, changing uses and timing.
8.46	Create an energy management system to automatically monitor and control HVAC, lighting and other equipment.
8.47	Install transpired air heating collector (solar wall for ventilation air preheating
8.48	Convert mixing air supply system into displacement ventilation system to create a temperature stratification in spaces with predominant cooling needs and contaminant stratification in spaces with combined contaminant and heat sources. Displacement ventilation increase ventilation and heat removal efficiency in such spaces.
8.49	Install occupancy sensors with VAV system - setback temperatures and shutoff boxes
8.50	Use night precooling to reduce cooling energy consumption
8.51	Use temperature destratification fans to reduce temperature gradient in buildings with heating needs
8.52	Replace dehumidification session with reheat for desiccant dehumidification
8.53	Consider replacement of all air HVAC system with a combination of dedicated outdoor air system complemented by hydronic low temperature difference radiant panel heating and cooling system
8.54	Review current conditions in industrial facility and install new local ventilation, cooling and heating systems and controls of these and general HVAC systems to match new processes and loads
9	Air Compressors
	Typically compressed air system is the most expensive form of energy used in industrial plant – its efficiency from start to end use is around 10%.
9.1	Eliminate air leaks. A typical industrial facility that has not been well maintained could have a leak rate between 20% and 50%. Leak repair and maintenance program can reduce this number to less than 10%.

9.2	Heat recovery from cooling oil in screw compressors
9.3	Install liquid pressure amplifier on reciprocating compressor systems
9.4	Reducing compressor speed in over capacity system
9.5	Replace air compressor and add receivers
9.6	Automate blow-off nozzles on air compressor storage tanks
9.7	Check proper size of air pressure regulators and lubricators
9.8	Convert compressed air systems to distributed systems
9.9	Install automatic traps/drains in larger air systems
9.10	Install storage surge tanks to buffer compressed air load fluctuations
9.11	Install compressed air metering
9.12	Install gas meters
9.13	Optimize loading with multiple air compressors
9.14	Recover waste heat from air compressor cooling system. As much as 80 to 93% of the electrical energy used by industrial air compressor is converted into heat. In many cases 50 to 90% of the available thermal energy can be recovered for space heating, industrial process heating, boiler make-up water preheating, industrial drying, etc.
9.15	Reduce excessive line air pressure losses, i.e., increase pipe diameter
9.16	Reduce air line pressure. For individual applications that require a higher pressure, instead of raising the operating pressure of the whole system, the following equipment modifications should be considered: Use a booster Increase a cylinder bore Change gear ratio Change operation to off peak hours
9.17	Replace existing air compressors with more efficient units
9.18	Replace oversized air compressors
9.19	Use after coolers in multi-stage air compressors
9.20	Use energy-efficient air drying systems
9.21	Use larger area air-intake filters
9.22	Use cold outside intake air for air compressors. As a rule of thumb, each 5oF (3 °C) will save 1% compressor energy.
9.23	Equipment cooling, use cool air compressors with a closed loop system
9.24	Turn off unnecessary compressed air. Equipment that is no longer using compressed air should have the air turned off completely. This can be done using a simple solenoid valve.
10	Thermal Storage System
10.1	Install cool storage to save on electric bills. The concept behind cool storage systems is to operate the system during off-peak electricity hours, and use the stored coolness to satisfy a building's air conditioning needs. Avoiding peak electricity hours will reduce electric bills.
10.2	Install hot water storage to shave peaks of hot water usage. Hot water storage will reduce the size or the number of boilers to be used during the peak hot water usage hours
11	Heat Pump
11.1	Install add-on heat pumps
11.2	Install ground-water source heat pumps

11.3	Install secondary pumping systems
11.4	Replace air conditioning and heating units with heat pumps
11.5	Electric heater replacement on standby generators with a heat pump
12	Hot Water Heater
12.1	Install decentralized water heaters
12.2	Install desiccant cooling systems
12.3	Install water heater blankets on water heaters
12.4	Insulate hot water pipes
12.5	Insulate water storage tanks
12.6	Use energy efficient direct contact water heating systems (98 percent efficient)
12.7	Use heat pump water heaters
12.8	Use smaller water heaters for seasonal requirements
12.9	Heat recovery for water heating
12.10	Install water-loop heat pump systems
12.11	Reclaim heat from waste water
12.12	Install solar heating where applicable
12.13	Dishwashers (replacement) - install low temperature dishwashers that sanitize primarily through the use of chemical agents rather than high water temperatures
12.14	Dishwashers (retrofit) - install electric eye or sensor systems in conveyor-type machines so that the presence of dishes moving along the conveyor activates the water flow
12.15	Eliminate all single pass water use
12.16	Dishwashers (operational modifications) - limit water temperature and flow rate settings to manufacturer's recommendations. To avoid compromising the sanitation process, do not set water temperature below 180 °F
12.17	Reduce hot water consumption
12.18	Reduce operating hours for water heating systems
12.19	Install gray water heat recovery from showers, dishwashers, washing machines
13	Lighting
13.1	Use daylighting or sky lighting with dual-glazed low "e" glass
13.2	Install dimming control for areas close to windows
13.3	Install dimming controls for areas with skylights
13.4	Install high efficiency electronic ballasts
13.5	Install high-pressure sodium lighting in selected areas
13.6	Install LED exit signs
13.7	Install LED traffic signals
13.8	Install low pressure sodium lighting in selected areas
13.9	Interior and exterior lighting replacement
13.10	Make lighting control improvements
13.11	Install lighting for parking lots or athletic fields

13.12	Use occupancy sensors (where applicable)
1313	Reduce illumination levels
13.14	Remove or replace lenses
13.15	Replace all incandescent bulbs with compact fluorescent
13.16	Use high-efficiency fluorescent lighting
13.17	Use reflectors to provide more efficient lighting
13.18	Use task lighting with low ambient illumination
13.19	Use multiple switching for selected lighting levels in offices, conference rooms, etc.
13.20	Use natural lighting in perimeter office spaces
13.21	Use timers and photocells for controlling outdoor lighting
13.22	Recover heat from light systems
13.23	Install skylights
13.24	Rewire lighting and other systems to allow personnel to shut off sections of systems - rather than leaving entire systems running
13.25	Clean and maintain lighting systems
13.26	Reduce operating hours for lighting systems
13.27	Replace high bay metal halide to T8 or T5
13.28	Use only local task lighting if possible
13.29	Use reduced lighting levels for cleaning, night-time and security staff
13.30	Switch off exterior security lighting during daylight hours
14	Electric systems, Motors, Pumps, Fans
14.1	Correct power factors
14.2	Install energy-efficient transformers
14.3	Install electrical meters
14.4	Investigate cutting impellers on pumps to match loads
14.5	Motor replacement with high efficiency motors >10 hp
14.6	Power factor correction depending on tariff considerations
14.7	Reduce power system losses
14.8	Reduce demand charges through load shedding, operational changes, and/or procedural changes
14.9	Replace refrigerator with high efficiency units
14.10	Replace oversized electric motors
14.11	Replace transformer with amorphous type transformers
14.12	Use emergency generators during load shedding
14.13	Use variable speed drives
14.14	Reduce plug loads using devices to shut off equipment not being used
14.15	Reduce sewage pumping/sewage reduction
14.16	Replace air-driven motors with electric motors
14.17	Replace existing electric motors with premium efficiency motors (often a better choice than re-winding motors).

14.18	Use blower/fans instead of compressed air for cooling, drying, or blow-off operations
14.19	Use energy efficient air blow-off nozzles
14.20	Use energy efficient v-belts for air compressors
14.21	Check belt tension on electric motors
14.22	Checking for oversized pumps, that currently operate with a discharge valve in a throttled condition, to lower system pressure
14.23	Use emergency generators for peak electric load shaving
15	Water Conservation
15.1	Replace faucet (with units that have infrared sensors or automatic shut-off)
15.2	Install irrigation control systems
15.3	Install subsurface irrigation
15.4	Install water flow restrictors on shower heads and faucets
15.5	Install automated watering systems for landscaping, golf courses, etc.
15.6	Install covers on swimming pools and tanks
15.7	Install devices to reduce the time flushometers are letting water flow
15.8	Install devices to save hot water by pumping water in the distribution lines back to the water heater so hot water is not washed - for use in BOQs and homes
15.9	Install industrial waste/sewage metering
15.10	Install water metering
15.11	Landscape irrigation - install irrigation timers to schedule sprinkler use to off-peak, night, or early morning hours, when water rates are cheaper and water used is less likely to evaporate.
15.12	Landscape irrigation - use low flow sprinkler heads instead of turf sprinklers in areas with plants, trees, and shrubs.
15.13	Landscape irrigation - use sprinkler controls employing soil tensiometers or electric moisture sensors to help determine when soil is dry, and gauge the amount of water needed.
15.14	Landscape irrigation - use trickle or subsurface drip irrigation systems that provide water directly to turf roots, preventing water loss by evaporation and runoff.
15.15	Install low flow toilets
15.16	Install waterless urinals
15.17	Install water conservation device (reduced pumping and water heating)
15.18	Use water reclamation techniques.
15.19	Water conserving dishwashers
16	Regular maintenance plan. General
	Inspect to ensure dampers are sealed tightly.
	Clean coil surfaces.
	Ensure doors and windows have tight seals.
	Check fans for lint, dirt or other causes of reduced flow.
	Schedule HVAC tune-ups (the typical energy savings generated by tune-up is 10 percent).
	Check and calibrate thermostat regularly.
	Replace air filters regularly.

	Adjust fan speed and belt drives.
	Check valves, dampers, linkages and motors.
	Check/maintain steam traps, vacuum systems and vents in one-pipe steam systems.
	Repair, calibrate or replace controls.
	Cooling system maintenance
	Clean the surfaces on the coiling coils, heat exchangers, evaporators and condensing units regularly so that they are clear of obstructions. Adjust the temperature of the cold air supply from air conditioner or heat pump or the cold water supplied by the chiller (a 2° to 3°F adjustment can bring a three to five percent energy savings).
	Test and repair leaks in equipment and refrigerant lines.
	Upgrade inefficient chillers.
	Fuel-fired heating system maintenance
	Clean and adjust the boiler or furnace.
	Check the combustion efficiency by measuring carbon dioxide and oxygen concentrations and the temperature of stack gases; make any necessary adjustments.
	Remove accumulated soot from boiler tubes and heat transfer surfaces.
	Install a fuel-efficient burner.
	Upgrade fuel-burning equipment Install a more efficient burner. Install an automatic flue damper to close the flue when not firing. Install turbulators to improve heat transfer efficiency in older fire tube boilers. Install an automatic combustion control system to monitor the combustion of exit gases and adjust the intake air for large boilers. Insulate hot boiler surfaces. Install electric ignitions instead of pilot lights.

Appendix C: Example Level I Assessment Summary Table

ECM	Description	Investment (K$)	Savings (K$/yr)	Payback (yr)	Savings Category	Recommended Funding Sources
PL#1A, Ph 1 only	Install and test two EED on chrome plating tanks	153.5	33.6	4.57	E, M	ECIP
PL#1, Ph1 & 2	Install EED on all chrome plating tanks	984.8	251.7	3.91	E, M (S&H)	ECIP
PL#2	Control airflows and steam heating	212	82.9	2.56	E	ECIP
PL#3	Insulate hot plating tanks and rinse tanks	101	9.6	10.53	E	ECIP
PL#5	Allow hot plating and rinse tanks to cool down	2.5	5.2	0.48	E	ECIP
PL#6	Retrofit MAUs with low pressure drop filters	85	8.1	10.40	E, M	ECIP
PN#1	Enclose Drive-Thru Paint Booth #1 in Bldg. 208	79.8	21.0	3.79	E (P)	ECIP
PN#2	Enclose Drive-Thru Paint Booth #2 in Bldg. 208	132.4	21.3	6.23	E (P)	ECIP
PN#3	B299 Paint Booth 4 improvements	145.9	114.7	1.27	E (P)	ECIP
PN#4	B229 Paint Booth 5 improvements	49.7	63.1	0.79	E (P)	ECIP
HT#5	Heat Treat Ventilation Improvements	168.6	4.6	36.6	E (IAQ)	ESPC
FD#2	Improve ventilation in the foundry	TBD	TBD	TBD	E (S&H)	ESPC
WD#1	Install ergonomic extraction arms	121.6	9.2	13.24	E (IAQ,P)	ECIP
WD#2	Install Improved ventilation system	15.9	35.5	0.45	E (IAQ,P)	ECIP
BE#1	Improve B-220 working conditions and IAQ	273.2	61.6	4.43	E (TC)	ECIP
BE#2	Install high-speed doors where necessary	64	43.1	1.48	E (TC)	ECIP
BH#1	Improve ventilation in Rapid Response Mnfc. Cell	17.4	high	quick	E	O&M
BH#6	Install on/off dampers in B-220 supply air ducts	6	2.5	2.4	E	O&M
BH#8	Improve IAQ in B-299 manufacturing departments	low	high	quick	E (IAQ)	O&M
BH#9	Perform further energy savings measures in B-222	2.5	2.2	1.19	E	ECIP
LT#1	Install Task Lamps in Areas require additional lighting	72.1	58.9	1.22	E (P)	ECIP
FD#1	Replace Critical Foundry Equipment in B-212 W	744.1	354	2.1	P	WC
18 ECMs	Total of the economically quantified ECMs including PL#1 Phase 2 work	3261.1	1149.2	2.84	ALL	ALL
15 ECIP ECM with PL#1 Ph1 and Ph 2	Total of the economically quantified ECIP ECMs	2342.4	788.1	2.97		ECIP
15 ECIP ECM, but No PL#1 Phase 2	Total of the economically quantified ECIP ECMs, but no PL#1 Phase 2 work	1511.1	570	2.65		ECIP

Note: TBD=To be determine; E=Energy; M=Maintenance; S&H=Safety & Health; IAQ=Indoor Air Quality; TC=Thermal Comfort; P=Productivity; ECIP=Energy Conservation Investment Program; ESPC=Energy Savings Performance Contract; O&M=Operation & Maintenance; WC=Army Working Capital Fund;

Appendix D: Recommended Report Structure for Energy and Process Assessment

1. Title Page with the List of the Major Team Members and Their Affiliation
   a. ABSTRACT
   b. TABLE OF CONTENTS
      Industrial Energy and Process Assessment Report should be based on this model for the Table of Contents and provide a list of all identified savings opportunities, feasibility of implementation and the basis for potential savings using different technologies and measures.
   c. INTRODUCTION
      Target of the assessment, name of the facility, funding source, objectives, approach and scope.
   d. PROJECT ORGANIZATION, PLANING AND SCHEDULING
2. SUMMARY OF THE ASSESSMENT RESULTS WITH PROPOSED SAVING MEASURES, ECONOMICS AND PROPOSED IMPLEMENTATION STRATEGIES
   a. Audited Facility
      Introduction of the facility with short descriptions of the processes and other important factors.
   b. Energy Economics and Saving Potentials
      Description of the energy consumption levels, saving potentials and proposed measures. These descriptions can be divided into subtitles such as heat/electricity/water.
   c. Table 1. Summary of the Energy Consumption (heating, electricity, water) and saving potentials.
   d. Table 2. Summary of the Proposed Measures
3. GENERAL INFORMATION
   a. Facility
      (1) Name
      (2) Address
      (3) Buildings
      (4) Construction year and renovation and/or extension year(s)
   b. Building type
      (1) Volume and area

(2) Production Structure, Volume of Production and Personnel
Detailed description of the production processes, volume of production and personnel of the audited facility.

c. Utilities and connections to networks
Description of the heating/electricity/water/compressed air utilities available.

d. Operation and Maintenance
Description on operation/maintenance organizations, consumption monitoring and maintenance contracts.

4. ENERGY AND WATER CONSUMPTION AND COSTS
Total consumption, consumption by energy types, specific consumption and changes in consumption and costs during the last years. Important changes in factors such as production structure, volume of production or number of personnel (which have a significant effect on energy consumption) should also be described.

a. Energy and Water Supply
Detailed description of energy and water supply to the building and to manufacturing processes.

b. Total Consumption and Costs
Numerical and graphical presentation, also history data if available
(1) Heating
(2) Electricity
(3) Water
(4) Other utilities consumption and costs

c. Shares of Different Energies Used
Shares of all different energy types used shall be presented numerically All technical systems / equipment with an energy consumption share of more than 5 % shall be presented separately. The values can be based either on measurements or on calculations.

d. Energy Balance
All primary and secondary energy flows shall be presented graphically (Sankey diagram or similar) and numerically. Balances for sub-processes/process equipment/production lines can also be presented in section 7.
(1) Heating
(2) Electricity
(3) Consumption
(a) Power
(b) Water
(4) Other balances

5. BASIC SURVEY AND ENERGY CONSUMPTION OF BUILDING RELATED SYSTEMS
   Description of building and processes systems, main equipment, functional criteria and functional condition. All information shall be divided based on energy flow direction; production/transfer/supply point. The energy calculation criteria for the technical system should be based on at least annual totals.
   a. District and Distributed Heating Systems
   b. HVAC and other Mechanical Systems
   c. Electrical Systems
   d. Compressed Air Systems
   e. Building Automation System
   f. Cooling Systems
   g. Other Building Services Systems
   h. Building Envelope and Structures
6. BASIC SURVEY AND ENERGY CONSUMPTION OF PROCESSES RELATED SYSTEMS
   Description of processes related systems, main equipment, functional criteria and functional condition. All information shall be divided based on energy flow direction; production/transfer/supply point. The energy calculation criteria for the technical systems shall be based on at least annual totals.
   a. Water Heating Systems
   b. Steam Systems
   c. Hot Oil Systems
   d. Gas Systems
   e. Pressured Air Systems
   f. Process Ventilation Systems
   g. Process Cooling Systems
   h. Process Electrical Systems
   i. Process Plumbing Systems
   j. Other Process Related Technical Services Systems
7. BASIC SURVEY AND ENERGY CONSUMPTION BY PROCESS EQUIPMENT
   General processes information shall be provided in the section 3. This section shall include information on specific sub-processes and equipment which are included in the assessment.
   a. Sub-process/Process Equipment A
      (1) Functional Description
      (2) Energy Consumption/Balance
      (3) N Sub-process/Process Equipment B-N

8. PROPOSED ENERGY AND PROCESS SAVING MEASUES
   Description of all proposed energy process saving measures/technologies. Includes saving and investment cost analyses summarized in tables. Also, measures which were proposed but for some reasons not recommended for implementation shall be presented with respective calculations.
   a. Building Services
   b. Process Technical Services
   c. Process Equipment
9. APPENDICES. Information with a significant importance which cannot be presented as a part of the text report (because of limitation on the number of pages, quality of materials available, etc.) shall be presented as appendices.
   a. The following documents shall not be published as appendices:
      (1) full size plans - diagrams should be used instead
      (2) equipment schedules when this information is not collected during the audit
      (3) results of the measurements and their graphical presentations when the information is not important or the graphics do not have titles or legends
      (4) simple calculation formulas - calculation criteria are very important instead
   b. The basic principle concerning appendices is that information in the appendices is important to the project and it has a reference in the text.

Appendix E: Techniques and Instrumentation for the Measurement and Evaluation of Air Infiltration in Buildings

Introduction

In the design and construction of modern buildings the intent is to provide an airtight envelope and to provide controllable ventilation either naturally or mechanically. However, only few buildings are sufficiently airtight due to the failures in design, construction and lifetime of the building. In the buildings that are not sufficiently airtight:

- significant amount of energy is wasted with the exfiltrating air in winter and need to cool infiltrating air in summer;
- significant energy is wasted to control indoor air humidity, especially in humid climates;
- damage to structural elements may occur due to condensation;
- there is a need to reduce a risk of cold drafts in the occupied areas
- polluted air could enter the building and effect IAQ;
- construction has a reduced U-value.

There are several parameters that are currently used to quantify the air leakage rate through the building envelope: air permeability, air leakage index and the effective leakage area.

Air permeability is the leakage flow, m3/h, supplied or exhausted from the space by the air moving equipment, per m2 of building envelope area for a specified external to internal pressure difference of 50Pa: , e.g., 10m3/h m2 at 50Pa. Building envelope area used to calculate air permeability includes all the surfaces that is a boundary between the building and outside environment including the solid ground floor area.

The air leakage index includes the building envelope area, which is defined as an internal surface area of the external façade and is calculated from dimensions of walls, top floor ceiling (or underside of roof) without a solid ground floor area.

Effective leakage area, sm2, is another parameter to quantify an airtightness. It is measured as an area of an orifice having equivalent leakage to all leaks and openings in the building envelope combined:

$$\mu A = \frac{Q}{\mu * \sqrt{2\rho \Delta P}} \qquad \text{Eq D1}$$

where

Q	=	leakage flow, m3/s.
μA	=	effective leakage area, m2
μ	=	discharge coefficient, assumed to be equal 0.64 (when building cracks and apertures have sharp edges) or 0.8 (rounded edges);
ρ	=	air density, kg/m³
ΔP	=	reference pressure difference, Pa (typically ΔP is assumed to be 50Pa)

Many national buildings standards and codes include requirements for airtightness of the building envelope. An overview of these requirements is given in AIVC TN 55 "Review of International Airtightness, Thermal Insulation and Indoor Air Quality Criteria. 2001 and in the currently proposed European Standard PrEN 138829.

Air Leakage Test Techniques

The most common method of testing building air leakage is so-called blower door technique according to EN 13829ASTM Standard E1827-96 "Standard Test methods for determining Airtightness of Buildings Using an Orifice Blower Door". 2002. Application of this standard to testing small dwellings and in larger buildings is described in CIBSE Technical Memoranda TM23:2000.

Measurements are made by using a suitably rated fan to create incremental pressure differences between the interior and exterior of the building in the 10-100 Pa range. For each pressure increment the corresponding air flow rate through the fan is measured.

The instrumentation is frequently built into a door (i.e., a "blower door"), which temporarily replaces an existing entrance to the building. Alternatively the fan may be sealed into a window opening.

The air flow rate through the fan is most accurately determined by measuring the pressure drop across a calibrated orifice plate or nozzle situated within the fan ducting. Alternatively a vane anemometer or pitot static tube may be used. The Internal/external pressure difference is measured using a manometer, which is normally connected via a tapping in the blower door. To minimize the influence of ambient pressures, measurements should only be made during periods of low wind speed and negligible internal/external temperature differences.

Figure D1. Fan pressurization equipment setup for the barrack building testing.

The Largest fan currently available for "Blower Door Test" is BRE's BREFAN (72cfm or 32m3/s)

In the large and leaky buildings and especially in industrial facilities, like those shown in Figure .... , the equivalent area of cracks $(\mu A)_i$ in the building envelope, m², can be estimated using the following approach.

Figure D2. Fan pressurization equipment setup being used to test a building of 2000m² floor area (Courtesy of BRE, Watford UK).

Figure D3. Examples of industrial facilities where application of a "blow door" test technique is not feasible.

For test conducted during the warm period of the year:

Close all external apertures;

Turn on all systems of exhaust ventilation on the maximum airflow rate and measure airflow mass rate, $G_{i.exh}$, exhausted by each system;

Measure $\Delta P_{o.z.}$, a difference of static pressure inside the building (room) and outside at the level of the occupied/working zone (~1.8m or 6 ft) (Figure D4);

The total equivalent area of cracks in the building envelope $(\mu A)_{bldg}$, can be calculated using the formula

$$\sum(\mu A)_{bldg} = \frac{\sum G_{i.exh}}{\sqrt{2g\rho\Delta P}} \qquad \text{Eq D2}$$

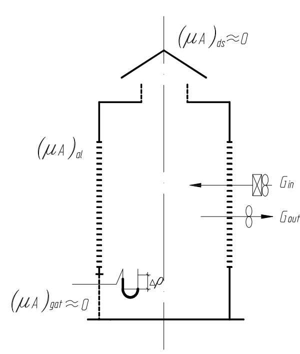


Figure D4. Pressure measurement in large and leaky buildings with distributed leaks.

When the test is conducted during the cold period of the year:

- Conduct tests with operating heating system and balanced operation of supply and exhaust mechanical ventilation systems;
- Measure the temperature of external air and temperature of internal air, averaged along the space/room height Δt;
- Measure the distance between the center of windows in the lower zone of the room (building) and in the upper zone of the room (building) h;
- Measure, a difference of static pressure inside and outside the building with an open $\Delta P_{o.z1}$ and closed $\Delta P_{o.z.2}$ large aperture (gate or any other big aperture in the external wall or a vent in the upper zone of a building) with the area A_0;
- Assume the value of the factor for the open aperture μ_o equal 0,64 (sharp edges of an aperture) or 0,8 (rounded edges);
- the equivalent area of the crack in the building envelope in the upper zone can be calculated using the equation:

$$(\mu A)_{u.z.} = \frac{(\mu A)_0}{M_1 - M_2} \qquad \text{Eq D3}$$

and in the lower zone:

$$(\mu A)_{l.z.} = (\mu A)_o M_2, \qquad \text{Eq D4}$$

where:

$$M_1 = 0{,}96\sqrt{\frac{0{,}0044 h \Delta t}{p_{o.z.1}} - 1}$$

$$M_2 = 0{,}96\sqrt{\frac{0{,}0044 h + \Delta t}{p_{o.z.2}} - 1}$$

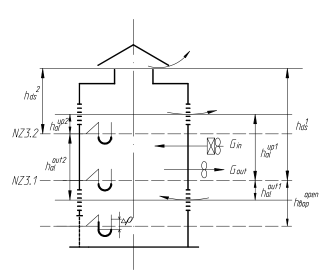


Figure D5. Pressure measurement in large and leaky buildings with leaks located in upper and lower zones.

Recommended Air Leakage Standards

Air leakage standard as summarized in the CIBSE Technical Memoranda

TM23:2000 are listed in Table D1.

Leakage Localization.

Leakage tests allow for estimation of air leakage, but do not indicate the location of the leakages. To find major leaks, critical locations (e.g., windows, roof/wall joint, pipe penetration, doors and other apertures or cracks in the building fabric several methods can be applied, e.g., smoke detection, anemometer or hand sensation during the fan-depressurization) (ASTM, Standard E1186-98, “Air Leakage Site Detection in Building Envelopes and Air Retrader Systems”. 1998)

The most promising way of detecting and visualizing leakages is infrared (IR) thermography. This test is based on a fan-depressurization test in winter. The cold outdoor air entering the room through the leakages cools down the warm inner surface near the leakages. This can be seen with the IP camera (Figure D6).

Table D1. Air leakage standards.

Building Types	Air Leakage, m^3 h-1m-2 at 50 Pa		Air Permeability, M^3 h-1m-2 at 50 Pa	
	Good Practice	Best practice	Good Practice	Best practice
Dwelling	15.0	8.0	10.0	5.0
Dwelling (with balanced whole house mechanical ventilation)	8.0	4.0	5.0	3.0
Offices (naturally ventilated	10.0	5.0	7.0	3.5
Offices (with balanced mechanical ventilation)	5.0	2.5	3.5	2.0
Superstores	5.0	2.0	3.0	1.5
Industrial	15.0	2.0	10.0	3.5

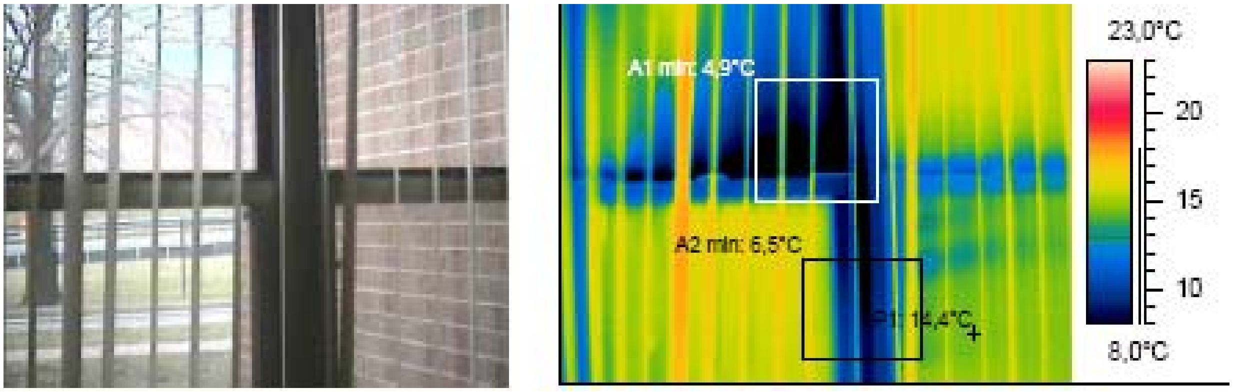


Figure D6. Inside view of the barrack building external wall. Air leakage through windows identified by fan-depressurization test.

Air leakage can also be observed from outside by conducting fan pressurization test. Warm building air passing through leaks heats the window and the adjacent wall (FigureD7)

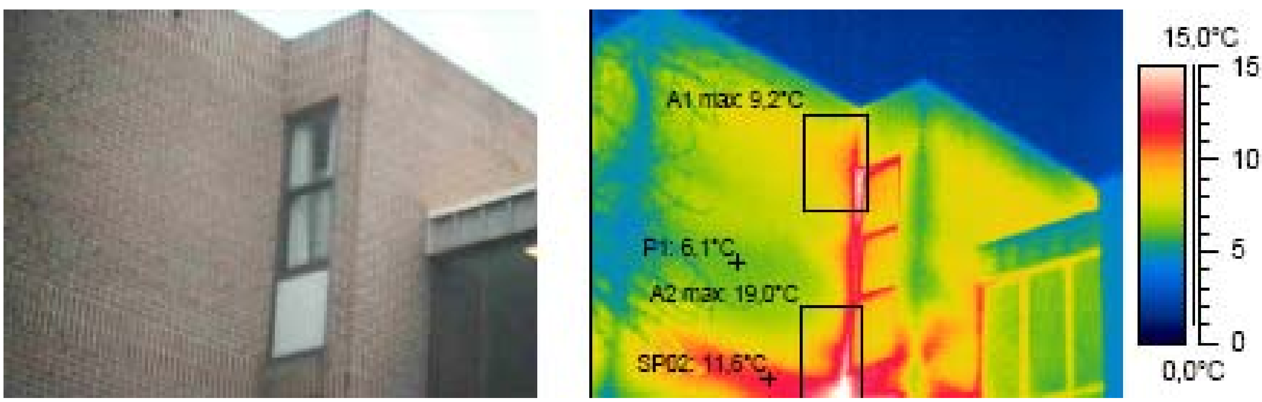


Figure D7. Outside view of the barrack building external wall. Air leakage through windows and cracks in the wall identified by fan-pressurization test.

Appendix F: Use of Thermography in Building Energy Assessment

In building energy assessment, IR thermography can be used in many applications, when monitoring the performance of buildings, building parts or structures, production processes, etc. This includes:

- locating a defective insulation
- locating air leaks
- checking windows and heat leakages
- detecting moisture damage
- locating objects within building parts, i.e., pipes, ventilation ducts, anchors, etc.
- examining the performance of heating systems, i.e., insulation defects, blockages in pipes, uneven supply of heat energy, malfunctions in the control units, etc.
- checking insulation on process equipment
- performing preventive maintenance
- checking electrical devices.

The modern radiometric (temperature measuring) infrared (IR) cameras are light, small-sized, and compact as standard camcorders. The thermal resolution is generally 0.1 °C or better, and the images can be saved on a memory card and/or videotape, along with text or spoken comments. The thermal images can be analyzed by specialized image processing software. Figure 2 shows a popular ThermaCam PM695 IR camera that is widely used in building applications; while in the figure3 a new small ThermaCam E2 model intended for quick monitoring and checking is presented.

Figure E1. An infrared camera (FLIR ThermaCam® PM-695).

- Handheld, 14-bit
- Temperature range: -40 + 2000 C
- Field of view/minimum focus distance: 24° x 18°/ 0.3 m
- Image frequency: 50/60 Hz non-interlaced
- Thermal sensitivity: 0.08 °C at 30 °C
- Spatial Resolution (IFOV) 1.3 mrad
- Size: 220 mm x 133 mm x 140 mm
- Weight: 1.9 kg, excluding battery
- 2.4 kg, including battery

Figure E2. An infrared camera (FLIR ThermaCAM® E2).

- Weight: 0,7 kg including battery
- Size (LxWxH): 265 mm x 80 mm x 105 mm
- Field of view/min focus distance: 25° x 19° / 0.3 m
- Thermal Sensitivity: 0.12 °C
- Detector Type: Focal plane array (FPA) uncooled microbolometer
- Spectral range: 7.5 to 13 μm

Table E1. Some applications of IR thermography for energy and process optimization assessment.

	Application
Boilers	1. Survey fire box for evidence of refractory deterioration.
	2. Survey boiler for evidence of air inleakage or exhaust.
	3. Survey blowdown lines, relief valves, drain isolations and other possible system penetrations for evidence of improper heat loss/leakage.
Steam Systems	1. Survey system drains/blowdown lines for system heat loss.
	2. Survey system steam traps for proper operation and evidence of excessive heat loss (ensure proper trap operation).
	3. Survey System lines for evidence of inadequate insulation
Hot Water Systems	1. Survey heat exchangers for proper operation and validation of installed instrumentation.
Pumps/Motors	1. Survey for indication of alignment problems.
	1. Survey for indication of bearing overheating
	2. Survey for indication of motor overheating
Building Envelope	1. Survey for evidence of air loss/inadequate insulation.
	2. Survey roof if time of year and weather conditions conducive to survey needs, i.e., dry roof, clear sky, evening hours.
Misc.	1. Survey radiant floor heating for evidence of coil leakage/blockage 2. Survey heating and cooling coils at VAV boxes and similar system heat exchangers for evidence of simultaneous heating and cooling..

Appendix G: Building Energy Balances

A building energy balance helps the energy auditor identify and account for all building energy inputs and outputs. Energy balances may be calculated or measured.

There is one major difference in calculated and measured building energy balances:

- The calculations have to assume certain conditions on climate, usage and system operation. Therefore they calculate energy demand under these conditions.
- The measurements on the other hand take into account the actual conditions including inefficiencies of systems, errors in operation, and wrong usage. Therefore what we measure are consumption data (metering) and quantities to calculate loads (e.g., temperatures or ventilation airflows)

How To Determine Heating Loads

An energy balance (kW, kWh) is expressed by the following equation:

$$Q_{\Sigma} = Q_{loss} + Q_{\inf} + Q_{vent} + Q_{hw} - Q_{\mathrm{int}.load} \qquad \text{Eq F5}$$

where:

Q_{Σ} = heating load brought into a building from external sources

Q_{loss} = Losses of heat through the building envelope; kW

$Q_{\inf}$ = Heat losses due to infiltration

Q_{vent} = Thermal load on ventilation,

Q_{hw} = Thermal load on hot water supply

$Q_{\mathrm{int}.load}$ = Internal thermal emissions, including heat recovery from the exhaust air.

Heat Losses Though Envelope

$$\mathrm{Q_{loss}} = \sum[\mathrm{k} * \mathrm{A} * (\mathrm{t_{room}} - \mathrm{t_{out}})] \qquad \text{Eq F6}$$

where:

Q_{loss} = Losses of heat through the building envelop; kW

k = Overall heat transfer coefficient of the envelop element, W/m²* °C

A = Area of the building element, m^2
t_{room} = Indoor air temperature, °C
t_{out} = Outdoor air or soil temperature, °C

Heating Load on Ventilation

$$Q_{vent} = \rho * C_p * q_v * (t_s - t_{out}) - Q_{HR}$$

where:

Q_{vent} = Thermal load on ventilation, kW
ρ = Air density, kg/m^3
C_p = Heat capacity of air, kJ/(kg*°C)
q_{vent} = Ventilation airflow rate, m^3/s
t_s = Supply air temperature, °C
t_{out} = Outdoor air or soil temperature, °C
Q_{HR} = Heat recovered from exhaust air by heat recovery equipment, kW

Heating Load Due to Infiltration

$$Q_{\inf} = \rho * C_p * q_{\inf} * (t_i - t_{out}) \quad \text{Eq F7}$$

where:

$Q_{\inf}$ = Heat losses due to infiltration, kW
ρ = Air density, kg/m^3
C_p = Heat capacity of air, kJ/(kg*°C)
$q_{\inf}$ = Infiltration airflow rate, m^3/s
t_{room} = Room air temperature, °C
t_{out} = Outdoor air or soil temperature, °C.

Infiltration airflow rate can be calculated as follows:

$$q_{\inf} = \sqrt{2(\mu F)_i \rho \Delta P_i} \quad \text{Eq F8}$$

where:

ΔP_i = the difference of static pressure between the air inside and outside the building, Pa, measured using a micro-manometer or calculated based on the difference in temperatures of external and internal air and the speed of a wind.
$(\mu F)_i$ = the equivalent area of cracks in the building envelope, m2, depends on a type of structures.

Techniques and Instrumentation for the Measurement and Evaluation of air Infiltration in Buildings are described in Appendix 2.

Internal Heat Gains

In defining the heating load of a building, the internal heat gains, $Q_{\text{int}.load}$ must be taken into account as much as it can be utilized in heating. The utilized heating effect recovered from exhaust air by heat recovery equipment considered di- Heat recovered from exhaust air by heat recovery equipment Q_{HR} is a part of the internal heat gain. The internal heat gain consists of heat released from process equipment, lighting, other electrical loads and people. In defining net internal gain, the heat gain through the building envelope must be taken into account. The internal heat gain shall also be taken into account when estimating the cooling load of the building.

Cooling Load

The cooling load of a building consists of heat released from internal and external sources:

- external factors:
  - solar radiation through fenestration and other parts of the building envelope
  - heat transfer through the building envelope due to warmer outside air
  - infiltration due to wind and a stack effect (gravity forces)
  - ventilation airflow rate
- internal factors
  - industrial processes such as machining, welding, heat treatment, etc.
  - electrical motors
  - process equipment with a high surface temperature
  - steam or hot water pipes, hot water tanks, etc.
  - lighting
  - people
  - computers , vending machines.

Cooling Load of HVAC System

If cooling is provided by HVAC system with a cooling coil, cooling load is calculated using the following equation:

$$Q_{cool} = \rho * q_{vent} * (h_s - h_{out})$$

where:

Q_{cool} = Cooling load of ventilation, kW
ρ = Air density, kg/m³
q_{vent} = Ventilation airflow rate, m³/s
h_s = Supply air enthalpy, kJ/kg
h_{out} = Outside air enthalpy, kJ/kg

Heating energy consumption

In general case, the heating energy consumption of a building can be calculated using the following equation:

$$Q = (Q_{loss} + Q_{\inf} + Q_{vent} + Q_{hw} - Q_{\text{int}.load}) / \eta$$

where:

Q = heating energy consumption, kWh
Q_{loss} = Losses of heat through the building envelope; kWh
$Q_{\inf}$ = Heat losses due to infiltration, kWh
Q_{vent} = Thermal load on ventilation, kWh
Q_{hw} = Thermal load on hot water supply, kWh
$Q_{\text{int}.load}$ = Internal thermal emissions, solar radiation and heat recovery from the exhaust air. kWh
η = efficiency of heat generation.

Heat Energy Losses through envelope

$$Q_{loss} = \sum [k * A * 24 * S] / 1000 + q_s * A$$

where:

Q_{loss} = Heat energy losses through the building envelope; kWh
k = Overall heat transfer coefficient of the envelope element, W/m²* °C
A = Area of the building element, m²
24 = Coefficient converting degree days to degree hours, hr/day
S = heating degree days, °C*days
1000 = Coefficient converting Wh to kWh
Q_s = Energy flow density through elements of envelope adjacent to soil, kWh/m²

Heating energy consumption of ventilation

$$Q_{vent} = \rho * C_p * q_v * \tau * 24 * 24 * S * r * t_w - Q_{HR}$$

where:

Q_{vent} = Heating energy consumption on ventilation, kWh
ρ = Air density, kg/m³
C_p = Heat capacity of air, kJ/(kg*°C)
q_{vent} = Ventilation airflow rate, m³/s
τ = operating time of ventilation system per day, h/24 hr/day
24 = Coefficient converting degree days to degree hours, hr/day
S = heating degree days, °C*days
r = Coefficient taking into account the daily operation time of ventilation
t_w = operation time of ventilation system/week, days/7 days
Q_{HR} = Utilized heating energy recovered from exhaust air by heat recovery equipment, kW

Heating Energy Consumption Due to Infiltration

$$Q_{\inf} = \rho * C_p * n_{\inf} * V * 24 * S / 3600$$

where:

$Q_{\inf}$ = Heating energy consumption due to infiltration, kWh
ρ = Air density, kg/m³
C_p = Heat capacity of air, kJ/(kg*°C)
$n_{\inf}$ = Infiltration airflow, air changes per hour, ACH or (m³/h)/m³
V = Building volume, m³
24 = Coefficient converting degree days to degree hours, hr/day
S = heating degree days, °C*days
3600 = Coefficient converting hr into sec

Cooling Energy Consumption

$$Q_{cool} = 24 * BLC * CDD / COP$$

where:

Q_{cool} = Cooling energy consumption, kWh
24 = coefficient converting degree days into degree hours
BLC = building loss coefficient, W/°C
CDD = Cooling degree days, °C*days
COP = Coefficient of performance of air conditioner

The accuracy of a building energy balances depends on many factors, including the accuracy of measuring devices, number of measurement points, duration of measurements, etc., but shall be better than 5÷15 % de-

pending on the size of the facility. When computing an energy balance, it is necessary to pay attention to operating modes of systems and the process equipment, conformity of parameters of a microclimate to design conditions, parameters of the heat-media, inertial properties (thermal stability) of a building and the equipment, dynamics of change of the outdoor conditions, etc. Computed energy balances allow estimation of heat consumption, calculation of specific systems parameters, and identification of areas where reduction of power consumption is feasible.

Appendix H: Rules of Thumb for Utility System ECMs

Rules of Thumb for ECMs are intended to provide energy professionals and part time practitioners with guidelines by which to identify and evaluate the potential of ECMs. The Rules of Thumb are shortcut methods, factors, typical percentage results, and formulas to calculate energy system ECO performance and to quantitatively analyze and estimate economics of savings and installed cost.

Energy Management and Economics

1.1 Plant Energy Audits**:** Initiate formal plant energy audits by trained audit teams that identify ECMs that can reduce the facility's Purchased Energy Cost (PEC) by 15 to 25 percent over a 1- to 3-year period with typical paybacks under 2 years.

1.2 Unit Energy Costs: Develop incremental, variable only, unit energy costs as a Cost Basis of Savings (CBoS) to value ECOs savings on a variable cost basis.

1.3 One Line Balance (OLBs): Develop One Line Balances for steam, electricity compressed air with an accuracy of ±20 percent. OLBs are used to identify opportunities in their respective utility system and to assist in providing a basis for quantities and cost saved.

1.4 Strategic Energy Plan: Implement a formal Strategic Energy Plan (SEP) with additional annual savings of 2 to 4 percent of annual PEC.

1.5 Energy Performance Index (EPI): Develop and track an overall Energy Performance Index (Btu/unit product) as a regression model to monitor program performance. Generally saves up to 0.5 percent of the PEC.

1.6 Plant Utility Indices: Establish and track plant utility indices as efficiency guidelines to save up to 1 percent of the annual PEC.

1.7 Savings resulting from accountability, accounting, troubleshooting, project verification, and overall feedback on the financial contribution from the EM Program.

1.8 Optimize Water Treatment: Optimize water treatment performance to save 2 to 5 percent of the annual cost of water treatment.

1.9 Shut it Off: Shut off energy to facility systems when not needed. Typically saves more than 1 percent of the annual PEC

Steam Systems

2.1 Boiler Efficiency: Optimize flue gas conditions to reduce percent O_2, flue gas temperature (°F), and CO concentration. Table 8 lists how the incremental changes in flue gas conditions improve a nominal 150 psi boiler efficiency.

2.2 Maximize Use of High Efficiency Boiler: Maximize the operating hours and loading of the highest efficiency boilers to typically reduce fuel consumption by 1 to 3 percent at zero cost.

2.3 Run Minimum Safe Number of Boilers: Operate minimum number of required boilers to safely and reliably meet the facility's steam needs resulting in typical savings of 3 to 6 percent of the annual fuel expense at no cost.

2.4 Reduce Boiler Steam Pressure: A 10 psig reduction in boiler pressure setpoint will reduce boiler fuel as shown (case where no steam turbines are used):
150-200 psig saves 0.2 percent
100-149 psig saves 0.4 percent
50-99 psig saves 1.0 percent

2.5 Heat Loss versus Insulation Thickness: 1 in. of insulation reduces bare pipe heat loss by approximately 70 percent; 2 in. reduces the remaining 30 percent loss by 70 percent or 21 percent for 91 percent total; 3 in. reduces the last 9 percent by 70 percent or 6.3 percent for a total of 97.3 percent. Two inches is the "economic" thickness for 80 percent of the applications. Well-insulated distribution systems for a 50 million BTUs/hr steam distribution system will typically have 2 to 4 percent heat loss. Losses for this system with average insulation performance will lose 6 to 10 percent while poorly insulated systems can

lose 15 percent or more. These losses through various quality of insulation are fixed losses independent of steam flow rate.

2.6 Pipe Insulation: Insulate Steam Systems when pipe surface temperatures are ≥160 °F cold climate or ≥190 °F warm climate. Fuel costs, inside/outside building and safety must also be considered. Paybacks usually occur in 18 to 48 months.

2.7 Removable, Soft Insulation: Install soft-cover, blanket insulation on uninsulated steam valve bodies and fittings will typically result in a 6-month payback for $3.00/mm Btu boiler fuel.

Steam Trap Losses: A typical steam trap loses 1 to 2 lb/hr of live steam during normal operation. A failed trap can lose 20 to 80 lb/hr of live steam. Replacement or repair can result in a payback of 1 month.

Steam Leaks: Establish a leak identification and repair program. Leaks for a well-maintained plant are < 1 percent, typically 2 to 4 percent, poorly maintained 10 percent or more. Table 9 lists “rules of thumb” for estimating the annual cost of steam leaks.

Sizing Condensate Lines: Condensate return piping should typically be 50 percent of the diameter of the steam pipe it serves.

HVAC&R Systems

3.1 HVAC&R Unit Costs: The incremental cost for HVAC heat is typically $5.00/klb ($3.00/MM Btu) and $50/k ton-hour ($0.05 /kWh) for chilled water cooling.

Table A5.1. How incremental changes in flue gas conditions improve a nominal 150 psi boiler efficiency.

Flue Gas	Efficiency Condition Change	Change
0_2 (percent)	-1.0 percent	+0.66 percent
Temp (°F)	-10 °F	+0.25 percent
CO (ppm)	-100 ppm	+0.10 percent

Table A5.2. Steam leak rules of thumb.

Rate Blow		Length (in.)	$/Year
Type	(lb/hr)		@5.00/Klb
Wisp	2	4	90
Small	10	12	450
Medium	30	36	1350
Large	170	72	7500

3.2 Chiller Efficiencies: The typical industrial centrifugal chiller operates at an approximately COP of 5.0 and 0.70 kW/ton (0.85 kW/ton with CHW and CT energy). A new, high efficiency, chiller can operate at 0.55 kW/ton (0.65 kW/Ton with CHW and CT energy).

3.3 HVAC & R Formulas: The following formulas are useful in calculating heating and air conditioning loads:

(a) Sensible Heat, Btu/hr = 108 x CFM x ΔT (°F)

(b) Total Cooling, Btu/hr = 4.5 x CFM x ΔH (Btu/lb dry air)

(c) Water Side, Btu/hr = 500 x GPM x ΔT (°F)

(d) Latent Load, Btu/hr = 0.67 x CFM xΔ Grains

(e) Fan Load, hp = CFM x ΔP (in. w.c.)/4000

(f) Duct Pressure Drop (in. w.c.) ΔP/100 ft = 0.15 in. w.c.

(g) Fan Laws: CFM, SP (Static Pressure), hp (Horse Power).

(1) $CFM_2/ CFM_1 = RPM_2/RPM_1$

(2) $SP_2/ SP_1 = (RPM_2/RPM_1)^2$

(3) $HP_2/HP_1 = (RPM_2/RPM_1)^3$

3.4 Increase CHW Temp: For each 1 °F increase in CHW supply setpoint the chiller compression motor load will DECREASE 1.5 percent. This is a zero cost ECO.

3.5 Decrease Conden. CTW Temp): For each 1 °F decrease in CTW to the chiller condenser, the chiller compressor load will decrease 1 percent. Zero cost ECO.

3.6 CTW to Centrifugal Chiller: Centrifugal SMC Chillers use 3 GPM of condenser CTW per ton with a 10 °F ΔT.

3.7 CTW to Single Stage Absorber: Single stage absorption refrigeration machines use 4.5 GPM of CTW per ton with an 18 °F ΔT. This is more than twice the cooling load of a centrifugal unit.

3.8 Steam to Single Stage Absorber: A single stage absorption chiller consumes 17 lb/hr of 15 psig steam per ton CHW produced.

3.9 Steam to Two-Stage Absorber: Two-stage absorption chillers consumes 10 lb/hr of 125 psig steam per ton CHW produced

3.10 Cooling Tower Efficiency: An efficient cooling tower will achieve a 7 °F approach to the current wet bulb temperature. Typically CT only achieve 9 to 12 °F approaches to wet bulb resulting in a 2 to 5 percent increase in chiller compressor load. CTW cost $0.08/Kgal. @$0.05/kWh.

Compressed Air Systems

4.1 Organize for Success: Form a small, part-time Compressed Air (CA) Team responsible for implementing CA ECOs.

4.2 CA Audit: Initiate a formal audit of CA generation, distribution, and use.

4.3 Unit Cost of CA: Incremental, electricity only, unit cost of CA is $0.18/KCF at $0.05/kWh, 24 BHP/100 SCFM and 20 percent for auxiliary.

4.4 Total Unit Cost of CA: Total, variable and fixed, unit cost of CA is $0.33/KCF; $0.18 electricity, $0.038 debt service, $0.025 operating

and maint. Labor, $0.025 materials and supplies and $0.012 taxes, insurance, miscellaneous. CBoS for CA is $0.18/kWh.

4.5 Critical Cost Issue List: Identify major critical cost issues (problems or opportunities) in the CA systems or operations that represent higher than normal annual costs.

4.6 Total Economic Impact of CA: Develop the total annual cost of CA on the facilities bottom line. This includes all direct costs (typically variable), indirect costs (typically fixed), and all consequential cost of CA such as reliability, product quality, environmental, etc., that are a direct consequence from a CA problem. Rule of Thumb 4.4 illustrates variable and fixed costs of $0.18 and $0.15/kch. Consequential cost might add another $0.03 to $0.07/kch.

4.7 One Line Balance: Develop by team estimates the CA flow (KCFM) and cash flow (K$/yr) that "accounts" for all generation distribution (by psi level) to all major users.

4.8 Pattern of Use: Estimate a typical 7-day system load profile (maximum, average, minimum), load duration curve, and hours of use of major compressor units as a base case for identifying and quantifying CA ECOs.

4.9 Run Minimum Number Machines: Operate the minimum number of machines to reliably, safely, and economically meet facility requirements.

4.10 Maximize Use of Efficiency Machines: Maximize the operating hours at optimum load for the highest efficiency machines.

4.11 Balance Loads: Match output on machines of near equal efficiency to eliminate blowoff (venting).

4.12 Part Load Operation: Optimize part load efficiency by load following with reciprocating or rotary screw units to keep centrifugals from venting.

4.13 Minimize Blow-off (Venting): Integrate multiple large centrifugal units with special compressor controls to minimize blow-off, trend efficiency, and to diagnose mechanical problems.

4.14 Minimize Use of Least Reliable Machines: Identify the least reliable (and/or highest maintenance machines) to minimize use and evaluate replacement economics.

4.15 Intercooler Temperature: Economically provide optimum low temperature cooling tower water to intercoolers and aftercoolers.

4.16 Aftercooler Performance: The typical aftercooler should remove 70 percent moisture and requires 3 GPM of CTW per 100 SCFM.

4.17 Optimize CTW Treatment: Optimize cooling tower water treatment to provide good heat transfer (low scale) and reliability (low corrosion).

4.18 Once Through Cooling: Eliminate once-through cooling with city water by installing a cooling tower. Once through City water is $1.00/Kgal, CTW is $0.08/Kgal.

4.19 Lube Oil Cooler: Properly maintain lubricating oil cooler performance for efficiency and reliability.

4.20 Synthetic Lube Oil: Use synthetic oil on reciprocating and screw machines that are low oil consumers. Saves 1 percent energy.

4.21 Motor Drives: Specify energy efficiency motors to save 4 to 6 percent of motor load with 2-yr payback.

4.22 Alternate Drives: Evaluate back pressure steam turbine drives ($0.015/kWh) and/or reciprocating or combustion turbine drives in a cogeneration topping cycle.

4.23 COG Belt Drive: Replace standard V-belt with high-efficiency COG type V-belt saving 1.5 percent of drive energy for 3-month payback without shaft change.

4.24 Air Intake Location: Air intake should be from coolest location, typically outside. A 5 °F temperature difference reduces motor load by 1 percent. Compressor room air is often 10 to 40 percent hotter than outside air depending on whether it is summer or winter.

4.25 Inlet Filter ΔP: Maintain inlet filter ΔP below 6 to 8 in. of w.c. where 5 in. cost 1 percent of motor load.

4.26 Inlet Guide Vanes (IGV): Replace butterfly inlet valve with inlet guide vane (IGV) design to reduce compressor motor load by 2 to 4 percent with 9 to 18 months payback.

4.27 Energy Efficiency Dryers: Specify a high efficiency dryer such as "Heat of Compression" and operate unit properly. "Heatless" dryers are not recommended as they use and dump CA to regenerate desiccant.

4.28 Dew Point Control: Optimize dew point by controlling to meet requirements on "as needed" basis rather than timer controls.

4.29 Recover Heat of Compression: The heat of compression is typically rejected to the cooling tower. However, 95 percent of this heat (approximately 230,000 Btu/hr per 100 hp of compressor drive) can be recovered with a plate heat exchanger to preheat boiler makeup water. Air-cooled units can be directly used as building heat during winter and exhausted during summer.

4.30 PM Program: Establish a predictive and preventive maintenance program. A complete program typically saves 2 to 3 times its cost.

4.31Reduce Compressor Pressure: A 1 percent motor load savings for each 2 psig reduction in setpoint can result down to a point that is limited by the highest pressure user. This is a no cost ECO.

4.32 Point-of-Use Pressure Control: Allow the setpoint to automatically float based on a control signal from the highest-pressure user. This can generally average an additional 2 to 4 psig pressure reduction at the compressor.

4.33 Lower High Pressure User: Reduce the pressure requirements of the high-pressure user. These could be sticking air cylinders and/or unnecessary equipment or operator demands. An example is high-pressure paint sprayers versus HVLP units.

4.34 Reduce System ΔP: Identify and relieve piping system ΔP bottlenecks.

4.35 Air Traps: Establish a formal trap program. A failed trap can lose 10 to 100 SCFM costing $950 to $9500/yr @$0.18/KCF. Approximately $100/CFM-yr.

4.36 Fix Leaks: Industrial facilities leaks range from 10 to 40 percent of air production. A facility with 1000 SCFM of production at 25 percent leaks is losing approximately $24,000/yr. Typical leaks range from small 3 CFM @ $300/yr, medium 20 CFM @ $1,000/yr, large 30 CFM @ $3,000/yr. Purchase an ultrasonic leak detector ($1,000 to $3,500) to support the program.

4.37 ID Peakers: Identify and reduce CA loads that strongly contribute to peak demand. These users actually cost up to twice the average cost per CFM ($0.36 versus $0.18/KCF).

4.38 Optimize Processes to Use Less or Zero CA: Re-engineer CA out of the processes by technology and/or procedural changes. Savings of 15 to 40 percent have been achieved.

4.39 Storage Tanks: Install surge/storage tank at high volume, short period, pulsing users.

4.40 PRV for Emergency Supply: Install a normally closed high to low pressure system PRV for backup of low-pressure header.

4.41 Decommission Idle Distribution Legs and Machines: Install airtight blank flanges to isolate and depressurize idle legs. Valve off idle machines. If leaks are 25 percent and 20 percent of the systems are idle, then system-wide energy costs are reduced by 5 percent.

4.42 Management and CAT Feedback: Formally provide facility management with the financial contribution of the CA Program on a quarterly basis. Provide CAT members and "customers" economics on specific projects/programs as achieved.

Appendix I: BLCC (Building Life Cycle Cost Program)

The program was developed to support LCC evaluations, which are required for all Federal building construction projects. BLCC is used to evaluate life-cycle costs for a building and to evaluate the impact of energy and water cost saving measures on life-cycle costs. BLCC allows users to compare life-cycle costs for various energy and water conservation measures with user-supplied energy and/or water usage rates and prices. It allows users to decide between construction options (e.g., whether to use a higher initial cost energy system to reduce energy costs throughout the building life). Costs of different options can be compared. BLCC computes life-cycle costs, savings-to-investment ratio, net savings, internal rate of return, and cash flow analysis for project alternatives. BLCC complies with American Society for Testing and Materials (ASTM) standards related to building economics. Detailed information on BLLC is available from the Life-Cycle Costing Manual (NIST Handbook) for the Federal Energy Management Program, which can be downloaded from the following website: http://www.bfrl.nist.gov/oae/publications/handbooks/135.pdf

The BLLC program can be also downloaded from the following website:

http://www.eere.energy.gov/femp/information/cfm/register_blcc.cfm

The following illustrations show the input information required for the BLLC Program.

LIFE-CYCLE COST ANALYSIS

1. PROJECT IDENTIFICATION

*PROJECT TITLE*______________________________ *FY*____

*LOCATION*____________________________ *DoE Region*_____

*BASE DATE*______________ *SERVICE DATE*______________

*DESIGN FEATURE*______________________________

*CONSTRAINTS*______________________________

TYPE OF STUDY: [__] Energy and Water Conservation & Renewable Resources (FEMP) [__] Other (OMB A-94)

BASE CASE AND ALTERNATIVES FOR LCC ANALYSIS

(A) ______________________________

(B) ______________________________

(C ______________________________

(D) ______________________________

(E) ______________________________

Analyst________________ Phone__________ Date of Study_____

1. Project Identification
INSTRUCTIONS

Step 1. PROJECT IDENTIFICATION

- Enter project name and fiscal year.
- Enter location. Enter DoE region (from *Annual Supplement*).
- Enter Base Date and Service Date.
- Enter design feature to be evaluated.
- List constraints. Add page if needed.
- Designate study as energy conservation study or OMB study.

Step 2. BASE CASE AMD ALTERNATIVES

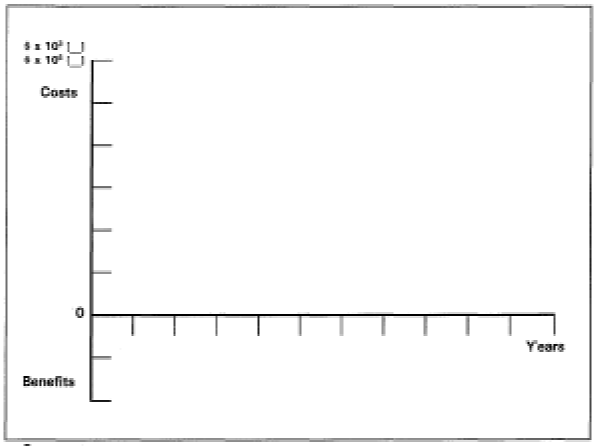
- Give title and brief description of base case and alternatives to be analyzed.

Step 3. GENERAL INFORMATION

- Enter name of analyst, phone number, and date study was completed.

LIFE-CYCLE COST ANALYSIS
2. CASH-FLOW DIAGRAM

Project Title____ **Alt. ID**______



Comments:

2. Cash Flow Diagram
INSTRUCTIONS

Step 1. KEY DATES

- Indicate years on horizontal axis and enter dates for Base Date (BD), Service Date (SD), and end of study period.

Step 2. CASH FLOWS

- Designate $-amounts as thousands or millions.
- Determine scale for dollar amounts on vertical axis.
- Enter anticipated cash flows:
  - Costs as positive amounts above the horizontal line (e.g., initial investment, energy, OM&R, disposal).
  - Benefits as negative amounts below the horizontal line (e.g., resale or salvage value).

LIFE-CYCLE COST ANALYSIS
3. INPUT DATA SUMMARY

Project Title____Alt. ID______

TYPE OF COST OR BENEFIT (1)	(2)	(3)		(4)		(5)	(6)	(7)
One-Time Amounts	$\$$-Amount on BD $\$ \times 10^3$ [ ] $\$ \times 10^6$ [ ]	Years from		Investment-related?		Data Source	Diff. Esc. Rate	Discount Factor Table
		BD	SD	Yes	No			No.
Annually Recurring Amounts	$\$$-Amount on BD $\$ \times 10^3$ [ ] $\$ \times 10^6$ [ ]	Number of Payments from		Investment-related?		Data Source	Diff. Esc. Rate	Discount Factor Table
		SD		Yes	No			No.
Water:								
Energy:							Diff. Esc. Rates for ENERGY Projects Embedded in Discount Factors	

BD = Base Date
SD = Service Date

3. Input Data Summary
INSTRUCTIONS

Step 1. IDENTIFICATION OF ALTERNATIVE

- Enter project title and identification data for alternative from *Project Identification* worksheet.

Step 2. ANALYSIS INPUT DATA

Col. (1) Enter types of costs or benefits as of the Base Date (BD):

One-time amounts:

Examples: Planning/Construction (P/C) or Acquisition Costs
Capital Replacement Costs
Major Repair Costs
Disposal Costs
Resale, Retention, or Salvage Value

Note: P/C or Acquisition Costs may be assumed to occur in a lump sum at the beginning of the study period. All other one-time costs are assumed to occur at any time during the analysis period, the specific time depending on when they are actually expected to occur.

Annually recurring amounts:

Examples: Routine OM&R Costs and Custodial Costs
Energy Costs: Electricity, distillate, residual, etc.,
Water Costs

Col. (2) Enter $-amounts as of the Base Date. (Designate as thousands or millions.)

Col. (3) For **one-time amounts**, enter the number of years after the Base Date (BD) and Service Date (SD) for which the costs or benefits occur.
For **annually recurring amounts**, enter the number of annual payments expected over the length of the study period.

Col. (4) Designate as investment-related or non-investment-related.

Col. (5) List data sources on a separate sheet and enter references here.

Col. (6) Enter differential escalation rate(s) for costs other than energy, if applicable.

Col. (7) Enter number of appropriate Discount Factor Table (for region, fuel type, sector, discount rate, differential escalation rate) from *Annual Supplement to Handbook 135.*

The following table lists example LCCA output.

Table..... LCCA Results for the 15 ECIP ECMs

ECM	Total Invest-ment	First Year Savings	SIR	AIRR	Simple Payback (Years)	Annual Usage Savings (Cost) (MBtu)	
						Coal	Electricity
PL1A	$ 153,480	$ 33,556.0	3.84	10.2%	4.57	1,665	1,046
PL2	$ 211,960	$ 82,903.0	5.87	12.5%	2.56	7,908	5,802
PL3	$ 100,959	$ 9,590.0	1.42	4.8%	10.53	1,708	0
PL5	$ 2,511	$ 5,222.0	31.09	22.3%	0.48	930	0
PL6	$ 84,831	$ 8,159.0	1.45	4.9%	10.4	0	888
PN1	$ 79,760	$ 21,034.0	3.95	10.3%	3.79	2,972	655
PN2	$ 132,430	$ 21,253.0	2.4	7.6%	6.23	3,122	492
PN3	$ 145,860	$ 114,675.0	11.79	16.5%	1.27	13,386	529
PN4	$ 49,650	$ 63,114.0	19.01	19.3%	0.79	10,971	228
WD1	$ 121,555	$ 9,184.0	1.13	3.6%	13.24	1,469	123
WD2	$ 15,855	$ 35,505.0	33.55	22.8%	0.45	4,892	779
BE1	$ 273,235	$ 61,640.0	3.37	9.5%	4.43	10,277	593
BE2	$ 63,950	$ 43,106.0	10.08	15.6%	1.48	7,677	0
BH9	$ 2,642	$ 2,219.0	12.68	17.0%	1.19	0	335
LT1	$ 72,087	$ 58,870.0	12.33	16.8%	1.22	0	(170)
Total	$ 1,510,765	$ 570,030.0	10.19	16%	2.65	66,977	11,300

Note: All Analysis Based On 20 Year Life

LCCA Results for the 15 ECIP ECMs (Cont)

ECM	Discounted Savings (Cost) Over Project Life					
	Coal	Electricity Usage	Electricity Demand	Total Energy (Excludes Demand Savings)	Non-Energy	Total Operational Savings
PL1A	$ 139,766	$ 104,725	$ -	$ 244,491	$ 345,320	$ 589,811
PL2	$ 663,824	$ 581,005	$ -	$ 1,244,829	$ -	$ 1,244,829
PL3	$ 143,375	$ -	$ -	$ 143,375	$ -	$ 143,375
PL5	$ 78,067	$ -	$ -	$ 78,067	$ -	$ 78,067
PL6	$ -	$ 88,891	$ 34,242	$ 88,891	$ -	$ 123,133
PN1	$ 249,480	$ 65,587	$ -	$ 315,067	$ -	$ 315,067
PN2	$ 262,071	$ 49,276	$ 6,912	$ 311,347	$ -	$ 318,259
PN3	$ 1,123,665	$ 53,011	$ -	$ 1,176,676	$ 543,570	$ 1,720,247
PN4	$ 920,942	$ 22,816	$ -	$ 943,758	$ -	$ 943,758
WD1	$ 123,313	$ 14,117	$ -	$ 137,430	$ -	$ 137,430
WD2	$ 410,651	$ 78,273	$ 43,010	$ 488,924	$ -	$ 531,934
BE1	$ 862,686	$ 59,381	$ -	$ 922,067	$ -	$ 922,067
BE2	$ 644,433	$ -	$ -	$ 644,433	$ -	$ 644,433
BH9	$ -	$ 33,491	$ -	$ 33,491	$ -	$ 33,491
LT1	$ -	$ (17,058)	$ -	$ (17,058)	$ 905,950	$ 888,892
Total	$ 5,622,273	$ 1,133,515	$ 84,164	$ 6,755,788	$1,794,840	$ 8,634,793

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Alexander M. Zhivov, Dahtzen Chu, Mike C.J. Lin, Michael Chimack, Donald Kasten, Alfred Woody, Jorma Pietilainen, Timo Kaupinne, Timo Husu, Curt Bjork, Erja Reinikainen, Eugene Shilkrot, Fritz Schmidt, and Walt Smith

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14. ABSTRACT

As part of its research and reimbursable program, the Engineer Research and Development Center (ERDC) has developed the Energy and Process Assessment Protocol for Industrial Buildings and performed supporting showcase assessments at selected U.S. Army Installations. This effort was undertaken to help garrisons achieve energy reduction goals and meet EPAct 2005 mandates, and also to address production and maintenance needs at U.S. Army Arsenals and Depots. The Protocol is partly the result of an international collaboration under the International Energy Agency "Energy Conservation in Buildings and Community Systems" Annex 46, Subtask A.

A group of government, institutional, and private sector parties developed the Protocol to help users (facility energy managers, in-house energy assessment groups, companies providing energy assessments, universities conducting energy assessment, and Energy Service Performance Contractors) perform Industrial and Energy Optimization assessments. The Protocol is based on an analysis of information gathered from literature, training materials, documented and non-documented practical experiences of contributors, and successful showcase energy assessments at U.S. Army facilities. It addresses both technical and non-technical organizational capabilities required for successful assessment geared to identifying energy and other operating costs reduction measures without adversely impacting product quality, safety, morale, or environment.

15. SUBJECT TERMS

energy conservation	energy efficient	industrial facilities
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